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## *In This Issue*



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# WHERE THE HIGHWAY DOLLAR GOES

## A STUDY OF COST DISTRIBUTION IN THE CONSTRUCTION OF CONCRETE PAVEMENTS

Reported by J. L. HARRISON, Division of Management, U. S. Bureau of Public Roads

DURING the past few years, but more particularly since the beginning of the present business depression, there has been a good deal of reference to larger construction programs as a means of relieving unemployment. In the very nature of the case, an increase in activity in any line of construction work involves the employment of additional labor both on the job itself and in the preparation of the materials required in its execution.

All lines of construction work are valuable aids during seasons of unemployment but none is more effective as a means of providing widespread employment than highway construction, particularly of the higher types, involving as it does the direct employment of a considerable number of men on the job and the indirect employment of a far greater number, usually in the more thickly populated centers, in preparing materials, manufacturing equipment and supplies, and in transporting them.

The widespread influence of Federal-aid highway work is especially noteworthy. The Federal-aid road act, effective since 1916, provides that all highway funds must be apportioned to the States and be expended therein on the Federal system of highways. To date, as a result, the effect of Federal-aid highway expenditures has been felt in practically every county in the country.

In view of the foregoing, this article has been prepared, in which is set forth as definitely as available data will permit the extent to which expenditures for highway improvement provide employment. The considerable extent to which such expenditures contribute to the support of others than those directly and indirectly employed is not analyzed in this article.

It may be observed that the method of analysis followed in this article could be applied to any process of manufacture or to any activity involving the use of labor and salaried personnel. The results of such an analysis would show, in most cases, that the great bulk of expenditures are chargeable, either directly or indirectly, to the account of salaries and wages. It happens that the highway contracting business operates in general on a very narrow margin of profit; and this is also currently true of the activities indirectly connected with the construction of high-type roads, and concrete roads in particular—cement manufacture, the quarrying of aggregates, railway transportation, and coal mining. For this reason it is at least probable that the contribution to labor is higher in the case of road-building than in the case of many other industries. However, the chief advantage of increased highway construction during times of economic depression lies in the fact that it affords much direct employment and stimulates many lines of business activity at a time when such an impetus is greatly needed, while at the same time meeting the increasing demand for improved roads.

For the purpose of the present study, concrete pavement has been selected largely because it is widely used on the Federal-aid highway system, and because the effect of expenditures for pavements of this type is believed to be typical of the effect produced by expenditures on other high-type pavements as well. Furthermore, it is typical of the effect produced by expenditures for public works generally, which have a wider influence than might at first be supposed. The points at which the influence of different types of construction is applied differ, however. The erection of a steel bridge yields a different distribution of effect than is involved in the construction of a concrete pavement, and neither shows exactly the same distribution as the construction of a monumental building. But this is of little consequence, for though the application of effect is at different points, in all of these cases the general effect is much the same.

The discussion which follows shows that while about 80 to 90 per cent of the money expended for concrete pavement construction is ultimately paid out as salaries and wages, only about one-seventh or approximately 15 per cent is paid to those employed on the jobs where these pavements are being built.

Further analysis shows that about one-third of the cost of pavement is paid to producers of materials (sand, gravel, stone, cement, and steel) which are components of such construction. Another third is paid to the railroads and other transportation companies for transport service on account of the collection and delivery of these materials. A large part of the remaining cost is paid to the producers of equipment. In all of these fields the gross payments made by the contractor are further distributed by the producer or the manufacturer through his pay rolls and expense payments. Labor receives the major share of this distribution as the materials entering into highway construction are of little value in their original state. Values are created by the application of labor in manufacturing processes and in transportation.

Labor employed on the job in quarries and pits, cement mills, by railroads and other transportation agencies, in the steel mills, powder mills, blast furnaces, ore pits or deposits, by equipment and machinery manufacturers, and by producers and distributors of the materials and supplies used by the above agencies, receives some part of the dollar expended for highway construction. For the most obvious phases of such construction, i.e., laying the pavement, production of materials, and transportation of materials and equipment, about 15 per cent is paid to labor utilized on the job; about 12 per cent for labor in the quarries, mills, gravel and sand pits producing materials for the pavement; and about 14 per cent as salaries and wages to railroad and other transportation employees engaged in transport of materials to the job.

In addition to these operations, the equipment must be built; repairs and spare parts must be provided. Materials other than those cited above are required for equipment needs, all of which involve labor and additional transportation which again involves additional labor, with the final result that instead of the 40 per cent of cost allotted to labor employed on the most obvious phases of the work it appears that about three-quarters of the cost of the pavement is ultimately paid out as compensation for the work done in the processes, operations, and manufacture by which the multitude of raw materials are produced, manipulated, transported, and finally combined into the finished pavement. Thus, several times as much money is finally disbursed to labor in a widely diversified field of occupations as is paid to the labor actually engaged in laying the pavement.

Of the balance, which is made up of such items as profit, interest, rents, and charges for depletion, the major portion is reexpended as capital investment for new construction in some form, as for new factories or new buildings, where about the same proportion of the total expenditure is paid out in salaries and wages as is paid out in the highway field. When the salaries and wages resulting from such use of profits are added to the salaries and wages developed above, it will be found that about 90 per cent of all payments for the construction of concrete pavements is ultimately converted into salaries and wages.

The analysis is terminated at the point where further employment of the funds concerned takes the form of personal expenditures by the recipients of wages, profits, interest, rents, etc. This further turn-over of the money originally expended for highways undoubtedly acts as a stimulus to business in general; the present discussion, however, is concerned only with the share received by the labor and salaried personnel employed, directly or indirectly, in the construction of highways.

### COST ITEMS ANALYZED IN DETAIL

It will be of interest to examine these expenditures in greater detail, and for this purpose the following primary separation of the cost of concrete pavements has been made.

1. The direct cost of laying concrete pavement (production expense).
   - *a.* Labor.
   - *b.* Aggregates.
   - *c.* Cement.
   - *d.* Steel.
   - *e.* Equipment.

These items cover the labor employed in connection with the various operations incident to laying the pavement, the cost of all materials of which the pavement is composed and the costs represented by the equipment used.

2. Expense incurred in connection with laying concrete pavement other than for production.
   - *f.* Installation of plant.
   - *g.* Bonds and insurance.

There are always certain preliminary expenses incident to this work which must be met, such as the cost of getting on to the job, the cost of developing a working organization, and the cost of bonds and insurance.

3. Job margin.
   - *h.* Overhead.
   - *i.* Financing.
   - *j.* Net profit.

Overhead, which includes central office salaries, rented quarters, the cost of bidding, etc., together with the cost of financing, must be paid out of job margin. After these and related expenses are satisfied the remainder is the net profit on whatever money is invested in the enterprise.

Based on 1929 prices in three typical States we have the first column of Table 1, which follows, as being reasonably representative of the first or primary distribution of cost of an average concrete paving job. These costs per square yard, when reduced to equivalent parts of pavement work done to the extent of $1,000, result in the distribution that is used in tracing the conversion of moneys paid for the construction of concrete pavement into payments for salaries and wages.

TABLE 1.—*Primary distribution of cost of average concrete paving job, based on 1929 prices in 3 typical States*

| Item | Cents per square yard | Dollars per $1,000 expenditure |
|---|---|---|
| *a.* Labor | $0.26 | $141 |
| *b.* Aggregate | .60 | 324 |
| *c.* Cement | .60 | 324 |
| *d.* Steel | .05 | 27 |
| *e.* Equipment | .18½ | 100 |
| *f.* Getting on to job | .05 | 27 |
| *g.* Bonds and insurance | .04 | 22 |
| *h.* Job margin | .06½ | 35 |
| | 1.85 | 1,000 |

A distribution based on 1930 prices would differ somewhat from the above. A still greater divergence would be observed between a distribution based on current prices and the distribution given above. Indeed, such a distribution of the cost of concrete pavement as the one given above changes with every modification in the cost of labor or the cost of materials. It also changes as the average efficiency with which this work is handled changes, as well as with every improvement in methods and machines.

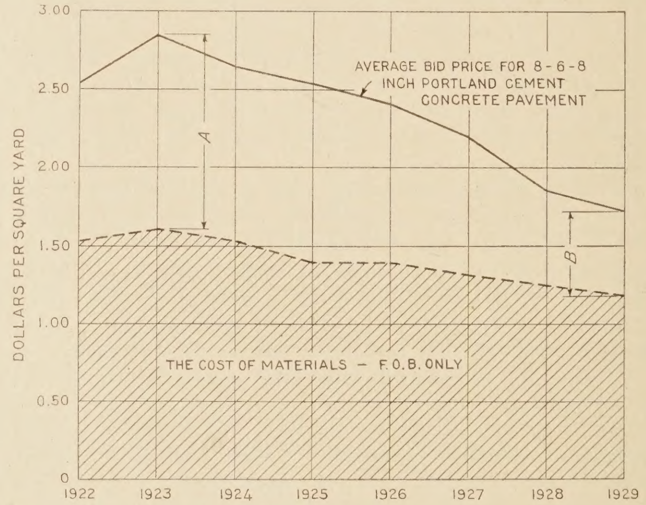


FIGURE 1.—TREND IN UNIT COST OF CONCRETE PAVEMENT FOR ONE STATE, DURING THE YEARS FROM 1922 TO 1929. THE MAXIMUM SPREAD, *A*, BETWEEN MATERIALS COST AND AVERAGE BID PRICE, IS $1.28; THE SPREAD IN 1929, *B*, IS NOT OVER $0.53

To show something of the nature of these changes Figure 1 has been included in this discussion. This figure is a graphical presentation of the trend in the cost of concrete pavement in one State, together with the trend in the cost of materials used in the concrete. It is to be observed that, while the cost of materials has decreased, the cost of the other elements has decreased quite as steadily and rather more rapidly. In short, such a distribution as that given in Table 1 is of momentary applicability only.

There would have been definite advantages in basing a discussion of this sort on current conditions rather than on those existing in 1929; but in an analysis of this sort much use must be made of figures regularly collected by the Bureau of the Census, and no figures collected by the Bureau of the Census on the subject of manufactures are available for any later date than the year 1929. Bureau of Internal Revenue figures have also been freely used and, when this analysis was made, these were not available for any later date than 1928.

# DISTRIBUTION OF THE HIGHWAY DOLLAR IN THE MARKETS OF THE NATION

The primary distribution of costs in Table 1 shows the labor directly employed on the job as Item *a*. For the purpose of showing a résumé of the labor indirectly employed Table 2 is given below. This table is made up of a series of statements showing the accumulation of labor costs as one item after another is broken down to show the included labor cost. The analysis is discontinued at the point (section 7) where the remaining items other than salaries and wages are in the form of payments to owners, i. e., owners of the business, of property, or of money used in the various businesses involved. The extent to which these items, interest, rents, profits, and reserve, are ultimately expended in salaries and wages is discussed in the latter part of the report. Following Table 2 is a presentation of the supporting evidence on which these statements are based.

*Item a. Labor.*—Table 1 indicates that 14.1 per cent of the cost of concrete paving is used directly in the payment of salaries and wages. In the production of concrete pavements labor is used directly in preparing the subgrade, in handling materials, in hauling them to the mixer, in operating equipment, and in taking care of the curing of the pavement, as well as for the purpose of accomplishing the numerous other details incident to this work. The general practice is to organize a paving crew which thereafter is of fairly uniform size and therefore of fairly uniform cost per working day. The labor element of cost listed above in the second column of Table 1 is the average cost of working this crew per $1,000 worth of Portland cement concrete pavement completed. The actual labor cost varies somewhat, the minimum being around $115 and the maximum around $175 with an average that appears to be not far from $141 of each $1,000 spent in this field.

This is not the whole cost of labor used directly on paving work, for, as will be developed in subsequent paragraphs, labor is used in getting on to the job and in preparing plant and equipment for the work of production that is to follow, and some expenditure for clerk hire, salaries, etc., is involved in overhead. As that part of the cost of pavement which is covered under the item labor is a matter of payments to labor used on the job, a further analysis of these payments is not required. The purpose here is to indicate the amount of the cost of pavements of this type which, in one way or another, is paid out as salaries and wages.

*Item b. Aggregates.*—Of the total cost of concrete pavement an average of about $324 per $1,000 spent is paid for aggregates (sand and gravel, stone, and slag) f. o. b. cars at the contractor's materials yard. This price includes two items: Freight charges and the cost of materials f. o. b. cars at points of origin—that is, at the quarries, gravel pits, sand pits, slag piles, etc., where these materials are produced. The data available are not in sufficient detail to indicate an exact division of cost between these two fields. In general, freight charges on aggregates run between 50 cents and $1.25 a ton, the average charge reported by several shippers being in the neighborhood of $1 a ton. This can not be far from correct as statistics published by the Interstate Commerce Commission (Freight Commodity Statistics, year ending December 31, 1929), show that during the year 1929 there were 81,408,069 tons of gravel and sand delivered to the railroads for shipment as revenue freight, and that the gross revenue

TABLE 2.—*Distribution of $1,000 paid for concrete highway, showing the approximate total amount which reaches labor in each of seven successive steps*

| | |
|---|---|
| (1) The contractor's distribution of $1,000 expended (Table 1, column 2): | |
| 1. Labor | $141.00 |
| 2. Aggregates | 324.00 |
| 3. Cement | 324.00 |
| 4. Steel | 27.00 |
| 5. Equipment | 100.00 |
| 6. Plant installation | 27.00 |
| 7. Bonding, etc | 22.00 |
| 8. Gross profit | 35.00 |
| | 1,000.00 |
| (2) After distribution of contractor's charges (see Table 3): | |
| 1. Salaries and wages | $302.70 |
| 2. Freight | [1] 406.70 |
| 3. Materials and supplies | [1] 30.15 |
| 4. Fuel | 35.50 |
| 5. Interest | 14.10 |
| 6. Taxes | 24.10 |
| 7. Depreciation and repairs | [1] 118.15 |
| 8. Depletion | 10.50 |
| 9. Profit | 48.10 |
| 10. For redistribution | 10.00 |
| | 1,000.00 |
| (3) After distribution of freight charges (see p. 30): | |
| 1. Salaries and wages | $477.70 |
| 2. Materials and supplies | 70.55 |
| 3. Fuel | 57.20 |
| 4. Interest, rents, etc | 61.70 |
| 5. Taxes | 49.70 |
| 6. Depreciation and repairs | 171.65 |
| 7. Profit | 91.00 |
| 8. Depletion | 10.50 |
| 9. For redistribution | 10.00 |
| | 1,000.00 |
| (4) After distribution of fuel costs (see p. 30): | |
| 1. Salaries and wages | $516.00 |
| 2. Materials and supplies | 77.20 |
| 3. Interest, rents, etc | 63.75 |
| 4. Taxes | 51.40 |
| 5. Depreciation and repairs | 175.75 |
| 6. Profit | 91.00 |
| 7. Depletion | 14.90 |
| 8. For redistribution | 10.00 |
| | 1,000.00 |
| (5) After distribution of depreciation and cost of repairs (see p. 31): | |
| 1. Salaries and wages | $568.70 |
| 2. Materials and supplies | 176.45 |
| 3. Interest, rents, etc | 65.50 |
| 4. Taxes | 55.80 |
| 5. Depletion | 14.90 |
| 6. Profit | 108.65 |
| 7. For redistribution | 10.00 |
| | 1,000.00 |
| (6) After distribution of cost of materials and supplies (see p. 31): | |
| 1. Salaries and wages | $730.90 |
| 2. Interest, rents, etc | 73.95 |
| 3. Taxes | [2] 39.45 |
| 4. Depletion | 17.95 |
| 5. Profit | 127.75 |
| 6. For redistribution | 10.00 |
| | 1,000.00 |
| (7) After distribution of taxes and $10 for redistribution (see p. 31): | |
| 1. Salaries and wages | $771.50 |
| 2. Interest, rents, etc | 81.30 |
| 3. Profit | 129.05 |
| 4. Reserve for depletion | 18.15 |
| | 1,000.00 |

[1] These items adjusted for freight charges assignable to materials, supplies, replacements, and repairs.
[2] This item adjusted for amount transferred to materials and supplies.

from this source was $69,420,839, or about 85 cents per ton. Crushed, broken, or ground stone produced 33,529,078 tons of revenue freight from which the revenue was $29,860,479, or a little over 89 cents per ton.

As a general rule quarries, gravel pits, and sand pits are located with their major markets, the larger cities, in mind. When the average freight charges are considered in the light of this fact, the average freight charge on materials sent to highway projects—about $1 a ton as given by the larger producers—does not appear to be estimated too high.

The Bureau of Mines (Sand and Gravel in 1928 and Sand and Gravel Production in 1929) gives the production and the value of paving sand and paving gravel produced in the United States as follows (average values as shown are computed from the figures given by the Bureau of Mines):

| | | Tons | Value | Value per ton |
|---|---|---|---|---|
| Paving sand: | 1927 | 35, 606, 622 | $17, 767, 491 | $0. 50 |
| | 1928 | 35, 244, 544 | 17, 305, 750 | . 49 |
| | 1929 | 40, 801, 991 | 21, 131, 731 | . 52 |
| Paving gravel: | 1927 | 44, 891, 975 | 29, 887, 365 | . 67 |
| | 1928 | 49, 088, 786 | 30, 697, 993 | . 63 |
| | 1929 | 60, 029, 164 | 38, 695, 207 | . 64 |

Similar figures on broken stone for concrete and road metal as released by the Bureau of Mines (Stone in 1928 and Production of Stone in 1929) are as follows:

| | | Quantity | Value | Value per ton |
|---|---|---|---|---|
| Broken stone: | 1927 | 78, 544, 210 | $84, 177, 237 | $1. 07 |
| | 1928 | 74, 384, 490 | 81, 041, 349 | 1. 09 |
| | 1929 | 76, 174, 770 | 80, 685, 493 | 1. 06 |

If the average freight charges on sand, gravel, and broken stone at $1 a ton are combined with the average sand and gravel prices given above, the following results:

| | Sand | Gravel | Broken stone |
|---|---|---|---|
| Average values per ton | $0. 52 | $0. 64 | $1. 06 |
| Freight charges per ton | 1. 00 | 1. 00 | 1. 00 |
| Value as delivered on the job | 1. 52 | 1. 64 | 2. 06 |
| Approximate price per cubic foot delivered | . 07½ | . 08½ | . 10½ |
| Percentage chargeable to freight | 66 | 61 | 49 |

These prices per cubic foot of aggregate delivered on the job are substantially in harmony with the average cost of aggregate given above—about 60 cents per square yard of pavement laid. Therefore, they are used as reasonably accurate and as indicating that the charges for freight absorb about 60 per cent of the cost of aggregate delivered on the job.

Meticulous accuracy would require a somewhat closer division of costs than this and a somewhat wider distribution of transportation charges, for some of the aggregate used in pavement construction is moved from points of origin to the site of the work in trucks, and a small fraction is barged. However, no exact data on the amounts so handled are available. The great bulk of these materials move by rail and the division of cost f. o. b. contractors' yards, though an approximation, is as accurate as available figures will produce and quite accurate enough to yield significant results.

Concerning the distribution of the cost of sand and gravel f. o. b. cars at points of origin, the Bureau of the Census has released preliminary data under date of January 28, 1931. This release is based on the production during 1929 of 165,526,075 tons of sand and gravel in plants producing more than 25,000 tons annually. For this same period the Bureau of Mines reported a total production of 99,253,054 tons of sand and 123,318,851 tons of gravel. The average vlaue of the total production in both cases is about 50 cents a ton. Therefore, while it would seem that the figures collected by the Bureau of the Census omit a considerable tonnage of material produced by the smaller companies, it also is apparent that the average value of the product has not been disturbed by this situation.

The data as to the sand and gravel industry released by the Bureau of the Census includes the following information:

| | Amount | Per cent |
|---|---|---|
| Value of product, f. o. b. plant | $100, 016, 527 | 100. 0 |
| Salaries and wages, including contract work | 33, 470, 169 | 33. 5 |
| Supplies | 11, 666, 227 | 11. 7 |
| Fuel, including purchased electric power | 8, 573, 371 | 8. 6 |
| Equipment purchased during year | 6, 757, 694 | 6. 8 |

The census of mines and quarries for the year 1919 gives the following data as to quarrying costs:

| | All rocks | Limestone only | Per cent [1] |
|---|---|---|---|
| Capital | $148, 759, 533 | $82, 124, 367 | ------------ |
| Salaries | 7, 168, 303 | 3, 726, 593 | 7. 0 } 53. 5 |
| Wages | 45, 534, 798 | 23, 926, 332 | 45. 2 } 53. 5 |
| Contract work | 995, 976 | 665, 557 | 1. 3 } 53. 5 |
| Materials and supplies | 18, 441, 459 | 10, 968, 220 | 20. 8 |
| Fuel | 5, 267, 846 | 2, 897, 432 | 5. 5 |
| Purchased power | 2, 213, 459 | 1, 278, 958 | 2. 41 |
| Royalties and rents | 1, 381, 290 | 667, 751 | 1. 35 |
| Taxes | 2, 088, 170 | 1, 119, 861 | 2. 01 |
| Total expense | 83, 091, 301 | 45, 250, 704 | 85. 6 |
| Total value, all products | 101, 684, 919 | 52, 943, 924 | ------ |
| Value of stone produced | 100, 423, 476 | 51, 967, 290 | ------ |
| Value of other products | 1, 261, 443 | 976, 634 | ------ |
| Stone produced, tons | 67, 884, 000 | 49, 715, 000 | ------ |

[1] Percentage which each item in the column headed "Limestone only" bears to total value all products, $52,943,924.

Since these figures were collected there has been some change in quarry practices but, on the whole, rather less than in most production fields, for the general methods followed in quarrying, handling, crushing, and loading stone are very much the same to-day as they were 10 years ago. Therefore, though production has risen a good deal (being given by the Bureau of Mines as 136,345,130 tons in 1927, 133,869,510 tons in 1928, and 141,109,580 tons in 1929) the cost distribution has changed only a little. This may be seen from the fact that the Bureau of Mines shows 22,967,579 man-days worked during 1929. (Quarry Accident Statistics.) Reports issued by the Bureau of Labor Statistics (Trend of Employment and Labor Turnover, October, 1930, p. 2, and Monthly Labor Review, April, 1930, p. 158) indicate that the average weekly wage, full time worked, in the quarries operated by cement companies was a little under $30 a week. Assuming that the wages paid in independent quarries were about what they were in the quarries owned by the cement companies, labor cost in 1929 could not have been much, if any, over $110,000,000 and probably was about $103,000,000. The total value of the stone marketed was $202,692,762, so that the labor fraction probably exceeded 50 per cent of the value of the stone f. o. b. cars at the quarries.

In the statistics issued by the Bureau of Mines, nondimension stone is charged with 14,987,172 man-days of labor, which, at the figures given above, must have cost somewhere between $68,000,000 and $75,000,000. Nondimension stone is assumed to include:

| | Tons | Value |
|---|---|---|
| Crushed stone | 92,721,260 | $94,387,878 |
| Furnace flux | 24,393,500 | 18,024,910 |
| Refractory stone | 1,558,200 | 1,807,324 |
| Agricultural limestone | 2,654,580 | 3,764,775 |
| Manufacturing industries | 7,430,749 | 6,361,201 |
| Rubble | 907,810 | 1,324,681 |
| Riprap | 4,212,990 | 5,030,743 |
| | 133,879,089 | 130,711,512 |

From this it would also appear that the labor fraction in the cost of crushed stone is still somewhere between 50 per cent and 60 per cent of the total cost; in other words, that the 1919 cost distribution given above is not inapplicable to crushed stone production under current conditions.

Of the aggregates used in producing concrete pavements about 35 per cent is sand. There are no very reliable data as to the amount of gravel used as compared to the amount of broken stone used. However, it will be assumed that 45 per cent is gravel and 20 per cent broken stone, a distribution believed to be reasonably accurate.

If the figures for gravel and sand production costs and the distribution of the production cost of broken stone as given above are combined on this basis, it would appear that the following is a reasonable distribution for the aggregate field taken as a whole.

| | Per cent |
|---|---|
| Salaries and wages | 38 |
| Supplies | 14 |
| Power | 8½ |

These figures account for about 60 per cent of the value of the aggregates purchased; the balance, nearly 40 per cent, is unexplained in this statement. In the more complete distribution of this item the latest reports of the Bureau of Internal Revenue (Statistics of Income for 1928) give the following information which is at least reasonably applicable.

*Item 8. Mining and quarrying not elsewhere specified—Lessors and holders.*—(NOTE.—This item includes corporations, but not individuals, operating quarries, gravel pits and sand pits, as well as a fraction of other operations in the mining and quarrying field not otherwise listed.)

| | |
|---|---|
| Gross sales— | |
| Corporations reporting net income | $60,284,447 |
| Corporations reporting no net income | 46,917,270 |
| Total | 107,201,717 |
| Net income or deficit— | |
| Corporations reporting net income | 22,504,402 |
| Corporations reporting no net income | —16,817,324 |
| Total net income | 5,687,078 |
| Net income, per cent | 5.31 |

The figures published by the Bureau of Internal Revenue do not include a further distribution of Item 8, but for the mining and quarrying industry as a whole, the following figures are given:

| | Per cent |
|---|---|
| Cost of goods sold | 59.79 |
| Compensation of officers | 1.54 |
| Interest paid | 2.76 |
| Taxes paid, other than income | 2.22 |
| Bad debts | .32 |
| Depreciation | 5.74 |
| Depletion | 5.89 |
| Miscellaneous deductions | 16.36 |
| Net profit | 5.38 |
| | 100.00 |

Combining these figures with those developed above, it would appear that the following is reasonably representative of the distribution of costs in the production of aggregate:

| | Per cent |
|---|---|
| Salaries and wages | 38.0 |
| Supplies | 14.0 |
| Fuel, including purchased power | 8.5 |
| Interest paid | 2.8 |
| Taxes, other than income | 2.2 |
| Bad debts | .3 |
| Depreciation | 5.7 |
| Depletion | 5.9 |
| Miscellaneous expense | 17.3 |
| Profit (5.3 per cent less Federal income tax) | 3.1 |
| Income tax | 2.2 |
| | 100.0 |

While miscellaneous expense no doubt contains a variety of items, in this particular field it is so largely a matter of repairs and replacements of equipment that it will hereafter be so treated.

Applying these figures to that part of each $1,000 spent for aggregates, the following table results:

| | |
|---|---|
| Proportion of each $1,000 spent for concrete roads generated by expenditures for materials | $324 |
| Freight | 194 |
| Salaries and wages | 50 |
| Supplies | 18 |
| Fuel, including purchased power | 11 |
| Interest | 4 |
| Taxes, including income tax | 6 |
| Bad debts, less than 50 cents | (1) |
| Depreciation and depletion | 15 |
| Repairs and replacements | 22 |
| Profit | 4 |
| | 324 |

*Item c. Cement.*—The cost of cement absorbs an average of about $324 out of every $1,000 spent on concrete pavement. The average cost of cement is fairly accurately indicated by the fact that during the fiscal year ended June 30, 1929, vouchers for Federal-aid payments included 4,278,485 barrels of cement listed separately. The cost of this cement, including freight, was $8,855,676 or an average cost of about $2.07 per barrel. During 1929 there were 25,008,203 tons of cement delivered to the railroads for shipment and freight charges to the amount of $67,083,562 were collected. This indicates an average freight charge of about 51 cents per barrel and an average value for the cement purchased separately for use on Federal-aid highway construction of about $1.56 per barrel. The figures published by the Bureau of Mines give the average mill price of cement as $1.62 during 1927; as $1.57 during 1928; and as $1.48 during 1929. The Bureau of the Census figures indicate an average value for 1929 of $1.53. This figure is based on a production of 169,868,322 barrels of Portland cement the value of which

[1] Dropped.

is given as $260,428,797. On the basis of 51 cents for freight and $1.48 as the 1929 price of cement, it would appear that about three-fourths of the cost of cement is a charge for cement at the mills, and that about one-fourth is a charge for freight; or, that of the $324 per $1,000 spent on pavements about $81 is paid for freight and about $243 is paid for cement f. o. b. cars at the cement mills.

As in other cases where freight is involved it is, of course, obvious that the railroads do not transport all of the materials shipped. Some of it moves in barges and quite a little moves in trucks; however, by far the larger part of the cement used in constructing highways moves by rail, so that for simplicity in analysis it will be assumed that it all does.

The census of manufacturers gives the following figures for the cement industry for 1927 shown in the first column and for 1929 the more limited information shown in the second column (Summary by Industries, 1929).

| | 1927 | 1929 | Value per barrel | |
|---|---|---|---|---|
| | | | 1927 | 1929 |
| Value of Portland cement produced | $287,431,268 | $260,428,797 | $1.66 | $1.53 |
| Salaries [1] | 16,331,586 | | .093 | |
| Wages [1] | 53,110,475 | 47,872,091 | .303 | .278 |
| Materials and supplies [1] | 59,495,154 | 92,599,816 | .339 | |
| Fuel and power [1] | 60,516,871 | | .345 | |

[1] These figures include natural and puzzolan cement, valued at less than 2 per cent of total value of all cement. They are obtained by dividing the costs shown in columns 1 and 2 by the corresponding production including natural and puzzolan cement (1927, 175,330,381 barrels; 1929, 172,052,493 barrels).

During the hearings before the Committee on Ways and Means (House of Representatives, 70th Cong.), representatives of the cement companies filed various documents dealing with the cost of producing cement. Table 2 from page 8,344 of volume 15 of these hearings, which is based on data reported by 101 plants, gives the information shown in the first column below. These figures are for the year 1927. The second column gives similar figures compiled from reports from 122 mills for 1929 which were presented before the United States Tariff Commission in connection with a recent hearing on the duties on cement.

| | 1927 cost in cents per barrel | 1929 cost in cents per barrel |
|---|---|---|
| Raw materials quarried and purchased, including labor | 20.12 | 20.11 |
| Fuel | 24.30 | 21.86 |
| Manufacturing labor | 14.21 | 11.49 |
| Packing and shipping labor | 4.07 | |
| Power, including labor | 13.19 | 11.62 |
| Other manufacturing expense, including labor | 14.63 | 14.81 |
| Packing and shipping, exclusive of labor | 5.44 | [1] 9.58 |
| General and administrative expense | 21.64 | 13.03 |
| Selling expense | 13.85 | 14.61 |
| Depreciation on buildings and equipment | | 11.77 |
| Inventory adjustment | | .26 |
| Interest on investment (computed at 6 per cent) | 19.14 | 19.50 |
| | 150.59 | 148.64 |

[1] Includes labor.

Another table given in the report of hearings before the Committee on Ways and Means (p. 8345), based on reports from a limited number of plants but believed to be reasonably representative, gives the 1927 labor costs of the following items not separately reported above as follows:

| | Number of plants reporting | Labor cost in cents per barrel |
|---|---|---|
| Quarrying | 82 | 5.40 |
| Power | 10 | 2.69 |
| Repairs | 12 | 2.73 |
| Laboratory | 8 | 1.31 |

The data presented to the United States Tariff Commission subdivides selling expense during 1929 as follows:

| | Cents per barrel |
|---|---|
| Salesmen's salaries and expenses | 6.98 |
| Commissions | .31 |
| Other selling expense | 7.32 |
| | 14.61 |

The figures given above indicate that the cost of raw materials did not change materially from 1927 to 1929. The cost of power dropped a little, presumably on account of changes in the cost of coal, and in the general efficiency of operation, which evidently was somewhat improved; for the Bureau of Mines reports 135.8 pounds of coal used per barrel of cement produced in the mills that used coal as fuel in 1927, against a consumption of 132.3 pounds per barrel in 1929. The cost of packing and shipping changed very little. Presumably the labor used in making repairs and the salaries and wages paid in the laboratories were equally stable.

In view of these facts it would appear that, exclusive of salaries and wages, which are a part of administrative expense or a part of selling expense, the cost of the labor used in producing cement during 1929 is indicated with reasonable accuracy by the following table:

*Labor costs per barrel of cement produced*

| | Cents per barrel |
|---|---|
| Manufacturing labor | 11.49 |
| Packing and shipping | 4.07 |
| Quarrying | 5.40 |
| Power | 2.69 |
| Repairs | 2.73 |
| Laboratory | 1.31 |
| | 27.69 |

This figure is in substantial agreement with the figure given by the Bureau of the Census—27.9 cents.

Financial reports of cement companies controlling about 44 per cent of the national production capacity indicate a bonded indebtedness in 1930 of $41,735,500, which suggests a total outstanding bonded indebtedness for the industry as a whole of about $95,000,000. Interest charges on this sum at 5 per cent amount to $4,750,000 and suggest an average interest change of about 2.8 cents per barrel of cement produced.

Depreciation is given above as 11.77 cents per barrel of cement produced. Financial reports of cement companies controlling about 44 per cent of the total production capacity show charges in 1930 of a little over $10,700,000 for depreciation and depletion, which suggests a total charge for all companies of about $24,400,000. As this charge does not change a great deal from year to year, it would appear that depreciation and depletion amount to about 14.3 cents per barrel. The difference, 2.53 cents per barrel, is, at least in large part, chargeable to depletion. However, this amount is somewhat more than an examination of various financial reports would indicate to be ordinarily allowed for depletion. For this reason depreciation and depletion are listed in the redistribution of cement charges as having the following values:

| | |
|---|---|
| Depreciation | $20.50 |
| Depletion | 3.00 |

For the year 1927 salaries as distinct from wages were reported by the Bureau of the Census as $16,331,586. Business conditions in 1929 were such as to make it probable that this figure is reasonably representative of costs during the latter year, which would suggest a charge of about 9.5 cents for salaries for the year 1929.

Taxes are not known with any great degree of exactness. The figures given by the Bureau of Internal Revenue (Statistics of Income for 1928) indicate that the taxes, including Federal income tax paid by the stone, clay, and glass industries, of which the cement business is roughly a quarter, amounted to a little over 2 per cent of the gross income. This would suggest a charge of about 3 cents a barrel on the cement produced.

On the basis of the figures given above, the cost of producing cement may be recast in the form used in this discussion, as follows:

| | Cents per barrel |
|---|---|
| Salaries and wages | 37.19 |
| Supplies (raw materials, less labor; shipping expense, less labor; and other manufacturing expense, less labor) | 32.30 |
| Fuel and power (less labor) | 30.79 |
| Interest | 2.80 |
| Taxes (unknown) | 3.00 |
| Depreciation | 14.30 |
| Miscellaneous expense | 8.76 |
| | 129.14 |
| Profit on the basis of Bureau of Mines average value | 18.86 |
| Bureau of Mines average value at mills | 148.00 |

The item miscellaneous expense was obtained by adding the items of general and administrative expense, selling expense, and inventory adjustment, as given in the cost per barrel figures submitted at the hearings of the Committee on Ways and Means (p. 26); and deducting items chargeable to those accounts which have been otherwise cared for in this analysis. On this basis we have—

| | | Cents per barrel |
|---|---|---|
| General and administrative expense | | 13.03 |
| Selling expense | | 14.61 |
| Inventory adjustment | | .26 |
| Total | | 27.90 |
| Less— | | |
| Salaries | 9.50 | |
| Laboratory labor | 1.31 | |
| Taxes | 3.00 | |
| Interest | 2.80 | |
| Depreciation in excess of that shown in previous table (p. 26) | 2.53 | |
| | | 19.14 |
| Miscellaneous expense | | 8.76 |

The largest items appearing in the materials and supplies account beside raw materials are estimated for the year 1927 as follows. (See testimony before the Committee on Ways and Means, 70th Cong., vol. 15, pp. 8295 to 8389.)

| | |
|---|---|
| Gysum | $5,822,498 |
| Explosives | 3,467,496 |
| Bags | 2,201,298 |
| Mill supplies and machinery | 21,695,496 |
| | 33,186,788 |

Of the above, explosives are of course a part of the charge for raw materials. If these are deducted the other materials listed generate a charge of about 17.2 cents per barrel of cement, which, with the reported cost of raw materials (less labor) at 14.71 cents, amounts to about 31.9 cents or about 2 cents less than the total the Bureau of the Census allocated to the item of materials and supplies (1927). This would seem to be a reasonably accurate cross check though it is probable that some of the cost of mill supplies and machinery as reported by the mills was generated by quarry operation and therefore may appear in the cost of raw materials.

Fuel and power are reported by the census (1927) as having cost $60,516,871, or 34.5 cents per barrel. The Bureau of the Census figures for 1929 do not segregate this item. The producers report—

| | 1927 (cents per barrel) | 1929 (cents per barrel) |
|---|---|---|
| Fuel | 24.30 | 21.86 |
| Power (including labor amounting to 2.69 cents, 13.19 cents for 1927, and 11.62 cents for 1929) | 10.50 | 8.93 |
| | 34.80 | 30.79 |

The Bureau of Mines (Cement in 1929, p. 409) gives the consumption of fuel in the production of Portland cement as follows:

| | | |
|---|---|---|
| Coal | tons | 9,340,434 |
| Oil | barrels | 2,533,911 |
| Natural gas | cubic feet | 41,643,433,045 |

Coal consumption was at the rate of 132.3 pounds per barrel of cement produced in the mills using coal as fuel, which would indicate that had coal been used exclusively the consumption would have been about 11,350,000 tons.

For 1929 the cost of fuel and power as reported by the cement companies, less 2.69 cents for labor, amounts to 30.79 cents per barrel or to something over $53,000,000. If for simplicity of analysis it is assumed that only coal was used for fuel, this would indicate a price of about $4.50 per ton delivered at the cement mills. Actually, the producers estimated the 1927 cost of coal as $42,330,074. The Bureau of Mines gives the amount of coal used in producing cement during 1927 as 9,990,531 short tons. This would indicate a price of a little less than $4.25 per ton, which must be very close to the correct figure, for the Bureau of Mines gives the average 1927 price of coal at the mines as $1.99. The average freight rate on bituminous coal is about $2.25.

The apparent cost of $4.50 noted above would seem to indicate either that the effective cost of oil and natural gas is a little higher than the cost of coal, or more probably that the total cost of fuel and power includes minor charges for oil, grease, etc. However, as the amount of charges of this nature is unknown, and as reasonable accuracy is preserved if the whole cost of fuel and power is assumed to be an expenditure for coal, further analysis will be on this basis. It would then appear that about 55 per cent of the cost of fuel and power, or about 16.9 cents per barrel of cement, is a charge for freight and that the balance, or substantially 13.9 cents, is a charge for the cost of fuel at the mines.

If the cost of mill supplies and machinery as given above for the year 1927 is divided by the production for that year, the resulting cost per barrel of cement produced is so close to the figure given for other manufacturing expense less the labor cost of making repairs as to suggest that other manufacturing expense is largely, if not entirely, a charge for repair and replacement parts. On this account the item supplies has been divided, repairs being charged at 12.08 cents per barrel and supplies and miscellaneous materials at 20.22 cents per barrel.

If the facts and the deductions made above are reduced to a statement of the number of dollars out of each $1,000 spent on concrete road construction each of these various items generates, the following table results:

| | |
|---|---|
| Total value of cement used per $1,000 expended | $324. 00 |
| Freight | 81. 00 |
| Cement at the mill | 243. 00 |
| Salaries and wages | 61. 00 |
| Repairs | 20. 00 |
| Supplies and materials | 33. 00 |
| Fuel | 22. 50 |
| Freight | 28. 00 |
| Interest | 4. 50 |
| Taxes | 5. 00 |
| Depreciation | 20. 50 |
| Depletion | 3. 00 |
| Miscellaneous expense | [2] 14. 50 |
| Profit | 31. 00 |
| | 243. 00 |

The distribution of the cost of cement is now in a form in which the items that require further analysis can be transferred to accumulations of other similar items. However, for a few of these items a little further comment may be appropriate. Repairs are, of course, an equipment charge and are so transferred. Depreciation also is an equipment charge. Both apply to a wide variety of machinery and equipment which, in general, requires constant expensive repairs in spite of which it depreciates rather rapidly.

Miscellaneous expense, which is largely selling and administrative expense, is composed of a long list of items which it is impracticable to separate. There is some travel expense which includes railroad fares and hotel expense. Probably there is some expense for office rentals. There certainly is a charge for association dues. Advertising is an element in this expense. Office supplies, advertising, folders, booklets, etc., generate some of it. As no information concerning the amount of these expenses is available and as travel expense generates at least a considerable part of them, and arbitrary assignment of about one-third of this expense to railroad expense has been made and the balance will be treated as miscellaneous materials, which much of it is though some of it is not.

*Item d. Steel.*—Steel, principally reinforcing steel but also including longitudinal joints, dowel steel, chairs, etc., is a highly variable element in the cost of concrete pavements. In the States on which the primary distribution of cost used in this discussion is based, the average use of steel is somewhat less than it is for the country as a whole. However, this is not of great importance here, for increasing the amount of steel would not change the general nature of the distribution of the cost of concrete pavements, though it would somewhat alter the proportions allocated to the various primary subdivisions.

An analysis similar to that used in distributing the cost of cement results in the distribution of that part of each $1,000 spent on concrete pavement which in this discussion is allocated to the purchase of steel, as follows:

[2] Railroad expense, $4.50; miscellaneous supplies, $10.

| | |
|---|---|
| Salaries and wages | $6. 00 |
| Coal | 1. 50 |
| Freight (of which $3 is freight on the finished product) | 6. 00 |
| Equipment, repairs, depreciation | 2. 50 |
| Materials | 8. 00 |
| Interest | 0. 40 |
| Taxes | 0. 90 |
| Administration and sales expense [3] (railroad expense 20 cents; supplies 50 cents) | 0. 70 |
| Profit | 1. 00 |
| | 27. 00 |

*Item e. Equipment.*—The cost of equipment—$100 out of each $1,000 spent on concrete pavements—represents equipment costs of three kinds: Depreciation, repairs, and operating expense. The latter, under the subdivision of costs used in this discussion, is largely a matter of fuel, lubricating oil, and minor incidentals. The labor used in operating equipment has been included with other job labor under Item *a*.

The size and the amount of the equipment used in laying concrete pavement, except the amount of hauling equipment, is rather uniform from job to job. Moreover, the specifications under which concrete pavements are laid, though not altogether uniform, are sufficiently so to generate a fairly constant rate of depreciation for each kind of equipment used. (See Depreciation Studies and Bulletin F, Bureau of Internal Revenue.) Field studies made by the Bureau of Public Roads indicate that the average value of the equipment other than hauling equipment used on concrete paving jobs is about $50,000. The value of the hauling equipment varies widely, partly on account of variations in the type of hauling equipment used and partly on account of wide variations in the distance materials must be moved. In occasional instances not more than three or four 1½-ton trucks are required. Where the haul distance is from 15 to 20 miles as many as 20 heavy trucks, worth well over $100,000, are required.

Under such conditions the average of even a considerable number of values obtained from field studies is not as certainly accurate as it appears to be in the matter of other job equipment the value of which is more nearly constant from job to job, but this average value, about $25,000, is at least approximately correct. The details of a reduction of these conditions to a charge for depreciation and a charge for repairs do not require repetition here. Neither do the details of other analyses.

In the nature of the case, repair costs are at least largely a matter of the cost of spare parts and the transportation charges on them. Little extra labor is involved since most repairs are made by the men who operate the machines and their time is included in the cost of job labor (Item *a*). In theory, depreciation charges may accumulate as cash; in practice, they are expanded for renewals about as fast as they accrue. Both repairs and depreciation are therefore equipment charges. The analysis of these charges is not repeated here but the results of these analyses are shown in the following table:

| | |
|---|---|
| Distribution of the amount allocated as a charge for equipment | $100. 00 |
| Primary distribution: | |
| Repairs and depreciation | 64. 00 |
| Gasoline and oil | 36. 00 |

[3] As in the case of a similar item in the distribution of the charges generated in making and marketing cement, this charge covers a multitude of minor items of which, as travel expense is of considerable importance, about a third is allocated as railroad expense and the balance as supplies, which in fact much of it is.

| | |
|---|---|
| Secondary distribution (gasoline and oil): | |
| Freight | $4.50 |
| Taxes | 6.80 |
| Wages (tank wagon) | 4.00 |
| Repairs and depreciation (tank wagon) | 4.00 |
| Profit | .20 |
| Wholesale cost of gasoline | 16.50 |
| | 36.00 |

| | |
|---|---|
| Third distribution (refining cost of gasoline): | |
| Salaries and wages | 1.20 |
| Materials and supplies | 10.65 |
| Fuel | .50 |
| Repairs | 1.85 |
| Interest | .20 |
| Taxes | .40 |
| Depreciation | .80 |
| Profit | .90 |
| | 16.50 |

| | |
|---|---|
| Combined totals: | |
| Salaries and wages | 5.20 |
| Freight | 4.50 |
| Taxes | 7.20 |
| Repairs and depreciation | 70.65 |
| Materials and supplies | 10.65 |
| Fuel | .50 |
| Interest | .20 |
| Profit | 1.10 |
| | 100.00 |

*Item f. Plant installation.*—The item of getting on to the job, amounting to about $27 out of every $1,000 spent on concrete pavement, covers the cost of sending equipment to the job (usually a freight charge), of erecting it, organizing, preparing to start construction, and placing equipment in storage ready for reshipment. The amount of exact information that is available regarding the cost of these various operations is limited, but such as has been collected indicates that about half of this item is a freight charge and about half a labor charge. Distributed on this basis, this item reduces to—

| | |
|---|---|
| Labor | $13.50 |
| Freight | 13.50 |

*Item g. Bonds and insurance.*—The reports of the Treasury Department for 1929 as to companies which issue surety bonds give the following data:

| | |
|---|---|
| Premiums collected, a little over | $57,310,000 |
| Losses and claims ... per cent | 43.5 |
| Commissions and brokerage ... do | 26.3 |
| Other expense (largely general overhead) ... per cent | 23.1 |
| Balance (reserves) ... do | 7.1 |

Bonds for highway purposes provided about one-fifth of the total premiums collected. Of the charges listed above, losses and claims are, in effect, payments toward construction and should therefore be distributed just about as original payments are distributed. Commissions and brokerage payments are, in effect, salaries and wages paid those who obtain business for the surety companies. Other expenses are so largely salaries and wages paid central office employees that they will be so considered. Actually some other charges—as rents, office supplies, advertising, etc.—are included in this item but the details are not of record.

While by far the larger part of the charge for bonds and insurance is a charge for surety bonds, a fraction is for workmen's compensation, which, in the very nature of the case, generates payments to labor; and a little is for liability and other forms of insurance. On the whole, however, a reasonably accurate view of this matter is had if of the $22 paid out of each $1,000 spent on concrete road construction for bonds and insurance, $11 is charged to salaries and wages, $10 is charged back for redistribution with other primary costs, and $1 is considered as profit. Actually, most of this $1 goes to reserves; but from the standpoint used in this discussion, reserves being the property of the concerns owning them, it has the general nature of profit. This item as fractioned above becomes—

| | |
|---|---|
| Salaries and wages | $11.00 |
| Redistribution | 10.00 |
| Profit | 1.00 |
| | 22.00 |

*Item h. Profit.*—Profit, as the term is used in this discussion, is job profit. Out of it there must be paid such items as administrative salaries, head office salaries, financing charges, office expenses, the balance, if any, being net profit. As to profit in this general field, which with several other lines of construction activity is covered by serial No. 54 in the classification established by the Bureau of Internal Revenue (Statistics of Income for 1928, p. 329) the following data appear:

| | |
|---|---|
| Gross income: | |
| Corporations reporting net income | $1,138,033,597 |
| Corporations reporting no net income | 375,245,267 |
| Total | 1,513,278,864 |
| Net income or deficit: | |
| Corporations reporting net income | 69,297,579 |
| Corporations reporting no net income | −32,728,384 |
| Total net income | 36,569,195 |

This would indicate an average net profit of a little more than 2 per cent on the volume of business reported. It is to be observed that these data cover only the corporations engaged in construction work. More than half of the total volume of all construction work is handled by individuals and by partnerships, generally only the larger and stronger concerns being incorporated. On this account it would appear to be reasonable to assume that the average net profit of corporations, partnerships, and individuals handling construction work is a good deal less than the average obtained by the corporations—possibly rather less than 1 per cent. This suggests that of the $35 set up as job profit per $1,000 spent on concrete pavements, about $10 may be set aside as a conservative estimate of net profit. Some of the balance of $25 is spent on administrative salaries not included in the salaries and wages under item *a* and office wages. A part is undoubtedly spent on financing and a part on taxes. The Bureau of Internal Revenue (Statistics of Income for 1928, Table 15) gives interest paid by construction companies as 1.04 per cent of gross, and taxes other than income tax as 0.48 per cent. Adding the income tax would bring this figure to slightly more than 1 per cent. There are, of course, a number of other minor items, but for the most part these have been included under the items previously discussed. In view of these facts, substantial accuracy would appear to be preserved if, on the undistributed balance given above ($25), $15 is assigned to office salaries and wages not included in item *a*, $5 to taxes, and $5 to interest payment. The following distribution results:

| | |
|---|---|
| Profit as defined above (job profit) | $35.00 |
| Office salaries and wages | 15.00 |
| Interest | 5.00 |
| Taxes | 5.00 |
| Profit (net) | 10.00 |
| | 35.00 |

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The distributions made and described above are summarized in Table 3.

TABLE 3.—*Summary of the various steps through which the contractor's payment of $1,000 are traced, and the amounts attributable to each*

| Item | Salaries and wages | Freight | Materials and supplies | Fuel | Interest | Taxes | Depreciation and repairs | Depletion | Profit | For redistribution |
|---|---|---|---|---|---|---|---|---|---|---|
| a. Salaries and wages | $141.00 | | | | | | | | | |
| b. Aggregate | 50.00 | $194.00 | $18.00 | $11.00 | $4.00 | $ 6.00 | $29.50 | $7.50 | $4.00 | |
| c. Cement | 61.00 | 113.50 | 43.00 | 22.50 | 4.50 | 5.00 | 40.50 | 3.00 | 31.00 | |
| d. Steel | 6.00 | 6.20 | 8.50 | 1.50 | .40 | .90 | 2.50 | | 1.00 | |
| e. Equipment | 5.20 | 4.50 | 10.65 | .50 | .20 | 7.20 | 70.65 | | 1.10 | |
| f. Plant installation | 13.50 | 13.50 | | | | | | | | |
| g. Bonds and insurance | 11.00 | | | | | | | | 1.00 | $10.00 |
| h. Job margin | 15.00 | | | | 5.00 | 5.00 | | | 10.00 | |
| | 302.70 | 331.70 | 80.15 | 35.50 | 14.10 | 24.10 | 143.15 | 10.50 | 48.10 | 10.00 |
| Adjustments [1] | | +75.00 | −50.00 | | | | −25.00 | | | |
| | 302.70 | 406.70 | 30.15 | 35.50 | 14.10 | 24.10 | 118.15 | 10.50 | 48.10 | 10.00 |

[1] These adjustments are made here to avoid recasting the freight analysis on account of freight allowances on repairs, replacements, materials, and supplies.

### FREIGHT COSTS ANALYZED

For the year 1929 the Bureau of Railway Economics gives the following interesting statement of the cost elements involved in operating railroads:

[Repeated here to 2 decimal places rather than to 4 as published]

| | Per cent | Distribution of $406.70 charges |
|---|---|---|
| Total salaries and wages, including executive management | 42.42 | $172.50 |
| Locomotive fuel, principally coal | 5.34 | 21.70 |
| Materials and supplies | 18.05 | 73.40 |
| Rent of cars and common facilities | 1.97 | 8.00 |
| Other expense (depreciation, loss and damage, injuries) | 5.66 | 23.00 |
| Taxes | 6.29 | 25.60 |
| Rent of leased roads | 2.73 | 11.10 |
| Interest | 7.00 | 28.50 |
| Dividends | 7.77 | 31.60 |
| Balance | 2.77 | 11.30 |
| | | 406.70 |

Of the above items some, as salaries and wages, can be used in the form in which they now stand; others require some further comment. Thus, materials and supplies cover the cost of repair parts for mechanical equipment as well as the numerous materials otherwise used in connection with the operation of our railroad system.

In the absence of more accurate information about half of this item, $37, is treated as repairs and the balance, $36.40, as materials and supplies. Rent of cars and common facilities and rent of leased roads cover payments for the use of facilities not owned. Accordingly they are included with interest in the column set aside for interest and rents as these items have a somewhat similar ultimate purpose. Other expenses is made up of two quite unreliable items. Depreciation, which is an equipment charge, generates about five-sevenths of the charge; the balance is made up of charges for loss and damage, injuries and insurance. In the last analysis, loss and damage payments are purchases of materials. It is also at least measurably correct to consider payments on account of injuries as salaries and wages. Of the charge for other expense $16.50 has therefore been allocated to depreciation, $4 to materials and supplies, and $2.50 to salaries and wages. Dividends and balance given above are, of course, profit.

If the totals from Table 3 are adjusted on the basis of this distribution, the following cost distribution results:

| | Amount | Redistributed railroad charges | Total |
|---|---|---|---|
| Salaries and wages | $302.70 | $175.00 | $477.70 |
| Materials and supplies | 30.15 | 40.40 | 70.55 |
| Fuel | 35.50 | 21.70 | 57.20 |
| Interest, rents, etc | 14.10 | 47.60 | 61.70 |
| Taxes | 24.10 | 25.60 | 49.70 |
| Depreciation and repairs | 118.15 | 53.50 | 171.65 |
| Profit | 48.10 | 42.90 | 91.00 |
| Depletion | 10.50 | 0 | 10.50 |
| Redistribution | 10.00 | 0 | 10.00 |
| | | 406.70 | 1,000.00 |

### FUEL COSTS REDISTRIBUTED

The latest information regarding labor and other costs incident to the production of bituminous coal is that published by the Bureau of the Census for the year 1929. Wages are reported as amounting to $574,800,072. Salaries are not reported for 1929. In 1919 they were slightly more than 10 per cent of the cost of wages. The value of the products, which includes a small amount for other than coal produced, is given as $966,693,771. It would therefore appear that salaries and wages absorb about 65 per cent of the value of the coal produced, which amounts to about 67 per cent of the coal sold. Information released by the Bureau of Internal Revenue (Statistics of Income for 1928) indicates that the industry, taken as a whole, operates at a loss. The following table gives the results of distributing the cost of fuel.

| | Amount | Redistributed coal costs | Total |
|---|---|---|---|
| Salaries and wages | $477.70 | $38.30 | $516.00 |
| Materials and supplies | 70.55 | 6.65 | 77.20 |
| Interest, rents, etc | 61.70 | 2.05 | 63.75 |
| Taxes | 49.70 | 1.70 | 51.40 |
| Depreciation and repairs | 171.65 | 4.10 | 175.75 |
| Profit | 91.00 | 0 | 91.00 |
| Depletion | 10.50 | 4.40 | 14.90 |
| Redistribution | 10.00 | 0 | 10.00 |
| | | 57.20 | 1,000.00 |

### MATERIALS AND SUPPLIES, REPAIRS AND DEPRECIATION ADD TO WAGE ACCOUNT

The two remaining items that involve the direct use of commodities are materials and supplies and repairs and depreciation. The number of commodities involved in these two groups is so large that even if the amount of each kind used were known exactly, the task of dividing each one into its constituent parts would be very great. Actually, the materials used are not known in detail, though often the more important materials are a matter of rather common knowledge. On this account, it is necessary to adopt a somewhat different method for the further study of this matter, which is possible because for every commodity separately classified the Bureau of the Census, in its census of manufacturers, gives "the value added by manufacture." This value is the difference between the value of the commodities manufactured and the cost of the materials, supplies, fuel and power used in producing them. The value added by manufacture then contains, first, the salaries and wages paid; second, all charges for depreciation; third, such miscellaneous items as taxes, interest and sales expense; and finally, profit.

Taking up first the further analysis of repairs and depreciation, a number of facts are apparent. The first of these is that while charges for depreciation may accumulate as cash reserve, as a general rule they are expended on renewals and improvements about as fast as they accrue. On this account they may reasonably be considered as expenditures for new equipment. Obviously, repair costs are such expenditures.

The second point deserving comment is that, as charges for repairs and depreciation are very largely generated by the plant and equipment used in manufacturing and in transporting, so much the larger part of these charges involves such items as machine tools, foundry and machine shop products, motor vehicles, motor vehicle bodies and parts, cars (railroad) and locomotives, it will be assumed that all of this charge involves these fields.

The third point to be noted is that, in the very nature of the case, charges for repair parts and for new machines include delivery costs, freight, or express. These charges should be estimated.

Upon adjustment of the table in the light of the results of the analysis of depreciation and repairs, the following distribution of expenditures results:

| | Amount | Repairs and depreciation | Total |
|---|---|---|---|
| Salaries and wages | $516.00 | $52.70 | $568.70 |
| Materials and supplies | 77.20 | 99.25 | 176.45 |
| Interest, rents, etc | 63.75 | 1.75 | 65.50 |
| Taxes | 51.40 | 4.40 | 55.80 |
| Depletion | 14.90 | 0 | 14.90 |
| Profit | 91.00 | 17.65 | 108.65 |
| Redistribution | 10.00 | 0 | 10.00 |
| | | 175.75 | 1,000.00 |

A similar analysis of materials and supplies results in the adjustments shown in the following table:

| | Amount | Materials and supplies | Total |
|---|---|---|---|
| Salaries and wages | $568.70 | $162.20 | $730.90 |
| Interest, rents, etc | 65.50 | 8.45 | 73.95 |
| Taxes [1] | 30.80 | 8.65 | 39.45 |
| Depletion | 14.90 | 3.05 | 17.95 |
| Profit | 108.65 | 19.10 | 127.75 |
| Redistribution | 10.00 | 0 | 10.00 |
| | | 201.45 | 1,000.00 |

[1] $25 deducted on account of materials and supplies and added to this account for redistribution here.

### TAXES SIMILARLY REDISTRIBUTED

Taxes are payments in support of government. Municipal, county, State, and Federal taxes are involved in unknown proportions. Interest payments absorb less than 5 per cent of the gross State revenues. They absorb something more than 15 per cent of the revenue of the Federal Government. (See Financial Statistics of States, 1929, Bureau of the Census.) The proportion of municipal and county revenue paid out as interest is unknown but is probably higher than the percentage reported as paid out by the States. In distributing taxes, it has been assumed that about 10 per cent is distributed as interest payments.

The pay roll absorbs a very large part of all government expenditures. The amount so absorbed is unknown but, aside from expenditures for public work salaries and wages are believed usually to absorb the greater part of the balance after debt service. As only a comparatively small amount of the taxes on business operations is spent in the highway field and as most other public works, except buildings and sewer systems, are presumed to be self-supporting, about 50 per cent of the tax taken out is allocated to salaries and wages and the balance—about 40 per cent—is allocated to the account of materials and supplies. On the basis of a preliminary calculation, as shown above, this was charged to materials and supplies as $25, which left a balance of $39.45 to be distributed, one-sixth to interest and five-sixths to salaries and wages. Distributed on this basis, interest amounts to $6.55 and salaries and wages to $32.90. The table now reduces to the following form:

| | Amount | Distribution of taxes | Total |
|---|---|---|---|
| Salaries and wages | $730.90 | $32.90 | $763.80 |
| Interest, rents, etc | 73.95 | 6.55 | 80.50 |
| Depletion | 17.95 | 0 | 17.95 |
| Profit | 127.75 | 0 | 127.75 |
| Redistribution | 10.00 | 0 | 10.00 |
| | | 39.45 | 1,000.00 |

If the $10 held for redistribution is now distributed under the headings now remaining, the following table results:

| | Amount | Distribution of $10 | Total |
|---|---|---|---|
| Salaries and wages | $763.80 | $7.70 | $771.50 |
| Interest, rents, etc | 80.50 | 0.80 | 81.30 |
| Depletion | 17.95 | 0.20 | 18.15 |
| Profit | 127.75 | 1.30 | 129.05 |
| | | 10.00 | 1,000.00 |

In this form the original expenditure is now divided into two classes of expenditures:

| | |
|---|---|
| Payments for salaries and wages | $771.50 |
| Payments to owners—that is, owners of the business, of property, or of money used in the various businesses conducted | 228.50 |
| | 1,000.00 |

This is about as far as the quantitative analysis may be carried with approximate certainty. If a further breakdown is attempted the quantities become somewhat doubtful; but there is still a further share for labor in the last quarter of the expenditure.

The preceding quantitative discussion is based on a period of unusual business activity. In times of depression such as the present, the residue composed of interest, rents, royalties, and profits shrinks both in absolute amount and in relation to the total. In view of this well known fact, it seems probable that, of the total expenditures for road construction at the present time, nearer 85 than 75 per cent may be thus directly traced into the hands of labor. Beyond this, there is still to be considered the fact that a part of the money paid to owners is immediately reinvested or expended, even in periods of depression, although a greater part is certainly so used in more prosperous times. And

(Continued on p. 38)

# THE RESISTANCE OF CONCRETE TO FROST ACTION

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THIS report gives the results of an investigation which was begun about six years ago for the purpose of determining how the resistance of concrete to frost action is affected by the character of the coarse aggregate used in the mixture. The tests were the first of a number of investigations to be started, all along the same general line, and including, among others, researches by C. H. Scholer at Kansas State Agricultural College; C. A. Hughes at the University of Minnesota, and the Portland Cement Association. The work was greatly hampered at the beginning because of a lack of information as to the proper procedure to be followed in making freezing tests in the laboratory. For this reason the original freezing cycle, which consisted of alternately saturating a large volume of concrete in water at 70° F. and then subjecting the specimens to an air temperature of about 20° F. in an ordinary cold storage room, proved entirely inadequate for the purpose.

This effort was followed by attempts to produce action through the use of lower freezing temperatures; that is, a minimum of about 5° F. Even under these conditions the action proved to be so slow that the method was finally abandoned in favor of an entirely different type of freezing cycle, as well as a different type of specimen. The results of tests by the third method, while somewhat contradictory and by no means conclusive, proved of considerable interest and it has accordingly been decided to report the data obtained, together with certain results obtained during work under the second cycle which appear to be significant.

In reviewing the data presented in this report the reader should bear in mind that these tests were of an exploratory nature. Very little was known about the subject when the work was started. Many mistakes were made and many things were done which it is now realized should not have been done. It is felt, however, that the results which have been finally obtained are of sufficient significance to justify the time and expense of carrying out this series of tests. In studying the data, however, it should be borne in mind that the results of tests involving individual materials should not be interpreted too literally, but should only be considered as indicating the possibility of certain trends which are of general significance only as they are substantiated by further work on aggregates having similar characteristics.

### CONCRETE SPECIMENS

The program called for the fabrication of 648 concrete beams 6 by 6 by 30 inches in size, using 18 different coarse aggregates of widely varying characteristics and three proportions, 1:1½:3, 1:2:4, and 1:3:6. Because of the fact that the stock of cement reserved for these tests was not quite sufficient to complete the series, it was found necessary to use a different cement in making up the specimens in which aggregates 2 and 15 were used. For this reason the results of freezing tests on these concretes are not included in Tables 5 and 6, although reference to the behavior of aggregate 15 in concrete is made in the discussion, because of certain interesting features in connection with this particular material. A standard Portland cement having the physical properties indicated in Table 1 and Potomac River concrete sand with properties as indicated in Table 2 were used in all specimens with the exception just noted. The coarse aggregates were all sampled at the point of origin by a representative of the bureau and were chosen so as to represent materials having a wide range in characteristics. Several sources were included which had previously been questioned because of failure in the sodium sulphate soundness test as well as others which were of unquestioned soundness. The types, character, and essential physical properties of the coarse aggregates used in these tests are given in Table 3.

TABLE 1.—*Tests of Portland cement. Results are the average of tests on six samples*

| | |
|---|---|
| Fineness: Retained on No. 200 sieve | 14.8 per cent. |
| Initial set | 3 hours, 40 minutes. |
| Final set | 6 hours, 25 minutes. |
| Tensile strength of 1.3 Ottawa sand mortar briquets: | |
| 7 days | 260 pounds per square inch. |
| 28 days | 355 pounds per square inch. |

TABLE 2.—*Tests of fine aggregate. Results are the average of tests on five samples*

| | Per cent |
|---|---|
| Sieve analysis: | |
| Retained on No. 10 sieve | 16 |
| Retained on No. 20 sieve | 31 |
| Retained on No. 30 sieve | 52 |
| Retained on No. 50 sieve | 81 |
| Retained on No. 100 sieve | 94 |
| Loss by elutriation | 2. 3 |
| Tensile strength ratio [1] (1:3 mortar briquets): | |
| 7 days | 112 per cent |
| 28 days | 110 per cent |

[1] As compared with 1:3 Ottawa sand mortar briquets.

TABLE 3.—*Characteristics of coarse aggregates used in freezing and thawing tests*

| Aggregate No. | Type | State | Mineral composition | Percentage of absorption | Percentage of wear [1] | Percentage of soft pieces [2] |
|---|---|---|---|---|---|---|
| 1 | Limestone | Maryland | Siliceous limestone | 0. 10 | 4. 2 | ------ |
| 2 | Gravel | District of Columbia. | Quartz, chert, gneiss, schist, sandstone. | . 51 | 8. 9 | 24 |
| 3 | do | South Carolina | Granular quartz | . 58 | 32. 6 | 91 |
| 4 | do | Pennsylvania | Sandstone | 1. 21 | 12. 3 | 20 |
| 5 | do | New Jersey | Granular quartz | . 51 | 27. 6 | 80 |
| 6 | do | Massachusetts | Quartz, granite, quartzite, schist, gneiss. | . 45 | 18. 3 | 28 |
| 7 | Dolomite | Ohio | Dolomite | 1. 36 | 9. 0 | ------ |
| 8 | Diabase | Connecticut | Diabase | . 20 | 2. 8 | ------ |
| 9 | Basalt | New Jersey | Basalt | . 10 | [3] 2. 0 | ------ |
| 10 | Limestone | Ohio | Crystalline limestone | [4] 2. 65 | [4] 7. 0 | ------ |
| 11 | Dolomite | Illinois | Dolomite | 1. 35 | [3] 5. 3 | ------ |
| 12 | Limestone | Minnesota | Argillaceous limestone | 1. 35 | ------ | ------ |
| 13 | Gravel | do | Dolomite, limestone, chert, granite, and shale. | . 49 | 7. 0 | 5 |
| 14 | Dolomite | Michigan | Dolomite | [4] 2. 24 | 7. 6 | ------ |
| 15 | Limestone | Illinois | Chert and limestone | 1. 90 | ------ | ------ |
| 16 | do | New York | Cherty limestone | . 08 | 4. 2 | ------ |
| 17 | Slag | Ohio | Porous blast furnace slag. | 2. 85 | (5) | ------ |
| 18 | do | do | Blast furnace slag | ------ | (6) | ------ |

[1] A. A. S. H. O. tentative standard method No. 3 for stone, No. 4 for gravel.
[2] A. A. S. H. O. tentative standard method No. 6.
[3] Average of several tests from this source. Test not made on sample used in this series.
[4] Material variable in quality. These are maximum values.
[5] No abrasion test made. Weight per cubic foot approximately 70 pounds.
[6] No abrasion test made. Weight per cubic foot approximately 85 pounds.

Each of the samples of coarse aggregate was regraded at the laboratory by passing it over a revolving screen equipped with sections having ¼-inch, ½-inch, ¾-inch, and 1¼-inch square openings. The concrete aggregate in each case was made up of the three fractions resulting from this screening, in the following proportions:

| | Per cent |
|---|---|
| ¼-inch to ½-inch | 20 |
| ½-inch to ¾-inch | 25 |
| ¾-inch to 1¼-inch | 55 |

A determination of the weight per cubic foot was made on each sample graded as above, and from this value the necessary weights of each size to be used in proportioning the concrete was calculated. Concrete was mixed with shovels in large galvanized iron pans, and molded into beam specimens 6 by 6 by 30 inches in size in accordance with a uniform procedure. Consistency was maintained by means of the flow test at approximately 140; that is, a medium consistency such as would be used in pavement work. All specimens were stored under wet earth for 28 days, after which the first freezing cycle was started. The wet earth storage was continued in the case of all specimens not being subjected to freezing and thawing.

For each aggregate 36 concrete beams were fabricated, 12 of each of the three proportions, 1:1½:3, 1:2:4 and 1:3:6. Eighteen specimens of each lot (6 of each of the 3 mixes) were subjected to freezing and 18 were stored under normal temperature conditions.

### SOUNDNESS TESTS OF AGGREGATES

In addition to the various routine tests, the results of which are given in Table 3, each coarse aggregate was subjected to five reversals in the sodium sulphate soundness test conducted in accordance with the tentative standard method of the American Association of State Highway Officials [1] as well as a direct freezing test conducted in accordance with the following method.

Representative samples of each aggregate weighing approximately 10 pounds were alternately saturated in water at 70° F. and then frozen in air at a temperature of about 0° F. An ice machine having a total capacity of 4 cubic feet was used for this purpose, as well as for freezing concrete during the third cycle. The aggregates were contained in small wooden boxes having copper screen bottoms. The samples were divided into two lots, one of which was frozen 8 hours and thawed 16 hours, while the other was frozen 16 hours and thawed 8 hours. At the end of each week the lots were reversed so as to equalize the severity of the freezing action. Progressive disintegration was noted by making visual examinations from time to time of the individual fragments composing each sample The results of the sodium sulphate and freezing tests on the aggregates are given in Table 4.

### FREEZING TESTS ON CONCRETE

*First cycle.*—As previously noted, the first freezing cycle consisted of saturating the full-size beams with water and then immediately removing them to a room having an air temperature of approximately 20° F. An attempt was made to freeze nine specimens of each lot (three of each mix) at one time, making a total of 162 specimens in the cold room, while a corresponding number were being thawed. The freezing room chosen for the work was one of the rooms in the cold storage plant of the Department of Agriculture at Arlington, Va. The room was 8 feet by 14 feet in size by 11 feet in height. Although previous tests had indicated that

[1] A. A. S. H. O. Tentative Standard method of test for soundness of coarse aggregate (T-9).

TABLE 4.—*Results of sodium sulphate soundness and freezing tests on coarse aggregates*

| Coarse aggregate No. | Type of coarse aggregate | Percentage absorption | Sodium sulphate soundness test | Freezing test: Alternations at first indication of failure | Per cent affected at end of alternations: 21 | 30 | 40 | 80 | 230 | 280 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Limestone | 0.10 | Sound | 21 | 5 | 5 | 5 | 5 | 5 | 5 |
| 2 | Gravel | .51 | do | 21 | | | 30 | | | 30 |
| 3 | do | .58 | do | 10 | | | 95 | 95 | 95 | 98 |
| 4 | do | 1.21 | Unsound | 21 | | | | | 50 | 50 |
| 5 | do | .51 | Sound | 10 | | | 95 | 95 | 95 | 98 |
| 6 | do | .45 | do | 21 | | | | 40 | 40 | 40 |
| 7 | Dolomite | 1.36 | do | (1) | | | | | | |
| 8 | Diabase | .20 | do | (1) | | | | | | |
| 9 | Basalt | .10 | do | (1) | | | | | | |
| 10 | Limestone | (2) | Unsound | 21 | | | | 30 | 60 | 60 |
| 11 | Dolomite | 1.35 | do | 21 | | | 5 | 5 | 5 | 5 |
| 12 | Limestone | 1.35 | do | 21 | | | 15 | 100 | 100 | 100 |
| 13 | Gravel | .49 | do | 10 | 5 | 5 | 5 | 5 | 5 | 5 |
| 14 | Dolomite | 2.24 | do | 10 | | 30 | 30 | 80 | 80 | 80 |
| 15 | Limestone | 1.90 | do | 10 | | | 80 | | | 85 |
| 16 | do | .08 | Sound | 80 | | | | 5 | 5 | 5 |
| 17 | Slag | 2.85 | do | 21 | | | | 10 | 10 | 30 |
| 18 | do | (3) | (3) | 21 | 1 | 1 | 1 | 1 | 1 | 60 |

[1] No action. [2] Variable; see discussion. [3] Test not made.

thorough freezing could be accomplished in about 24 hours, the capacity of the plant proved entirely inadequate for the volume of concrete which was to be frozen. This was demonstrated at the end of 50 and again at the end of 100 cycles of freezing and thawing, when tests for modulus of rupture of the frozen beams were made and the results compared to similar tests on unfrozen specimens. In neither case was there evidence of any deleterious effect of frost action, even in the 1:3:6 mixes.

*Second cycle.*—It was realized after these experiments that in order to increase the efficiency of the freezing plant to a point where it would be possible actually to freeze the specimens, it would be necessary to reduce very materially the number frozen at one time. In view of the time required to do this, it was decided to try freezing a full set of the 1:3:6 specimens in the cold-storage plant at the old Center Market, Washington, D. C., where it was possible to obtain not only lower temperatures (a minimum of about 5° F.) but also much greater capacity, resulting in more rapid freezing. This cycle consisted of alternately immersing in water at 70° F. and freezing in air at a minimum of 5° F. The duration of each complete alternation was 24 hours. The specimens subjected to this test were of the 1:3:6 mix and comprised beams which had already been subjected to 100 alternations at Arlington. Three beams for each aggregate were subjected to this cycle and at the conclusion of 70 alternations were tested for modulus of rupture in comparison with similar beams unfrozen. The concrete specimens at this time were approximately two years old. The results of these tests are shown in Table 5. It will be observed that there is, in all cases, a falling off in strength due to freezing. The extent of this reduction varies from 3 per cent in the case of aggregate No. 10, to 100 per cent in the case of aggregate No. 14. However, an examination of the data fails to show any definite relation between the soundness of the aggregate as revealed by either the sodium sulphate test or a freezing test and the soundness of the concrete. An inspection of the frozen specimens after test indicated that the reduction in strength was, in almost all cases, due to a weakening of the mortar rather than to the coarse aggregate. Exception to this conclusion may be noted in aggregate No. 14, a silicious and argillaceous dolomite. In this case action had progressed to the point where the concrete failed before any load could be applied. Failure was undoubtedly accelerated by action on the aggregate. It is of interest to note that concrete containing the two limestones and the dolomite which were sound by the sodium sulphate test (Nos. 1, 7, and 16) showed relatively high resistance to frost action, as did also one unsound limestone, No. 10. The two trap rock concretes, Nos. 8 and 9, although the coarse aggregates were of unquestioned soundness, showed low resistance, possibly because of some condition associated with bond between mortar and aggregate.

Table 5.—*Effect of alternate freezing and thawing on the flexural strength of concrete containing various types and grades of coarse aggregate. Each value average of tests on three specimens.*

| | |
|---|---|
| Proportions | 1:3:6 by volume. |
| Consistency | Medium. |
| Water-cement ratio | Approximately 1.40. |
| Age at test | Approximately 2 years. |
| Freezing treatment | 100 alternations, cycle No. 1<br>70 alternations, cycle No. 2 |

| Coarse aggregate No. | Type of coarse aggregate | Rating of coarse aggregate, sodium sulphate test | Modulus of rupture in pounds per square inch: Frozen | Modulus of rupture in pounds per square inch: Unfrozen | Percentage reduction in strength |
|---|---|---|---|---|---|
| 1 | Limestone | Sound | 354 | 373 | 5 |
| 3 | Gravel | do | 264 | 340 | 22 |
| 4 | do | Unsound | 266 | 348 | 24 |
| 5 | do | Sound | 271 | 340 | 20 |
| 6 | do | do | 244 | 384 | 14 |
| 7 | Dolomite | do | 390 | 435 | 10 |
| 8 | Diabase | do | 272 | 383 | 29 |
| 9 | Basalt | do | 341 | 418 | 18 |
| 10 | Limestone | Unsound | 435 | 440 | 3 |
| 11 | Dolomite | do | 341 | 452 | 25 |
| 12 | Limestone | do | 272 | 384 | 29 |
| 13 | Gravel | do | 360 | 478 | 25 |
| 14 | Dolomite | do | (1) | 454 | |
| 16 | Limestone | Sound | 362 | 432 | 16 |
| 17 | Slag | do | 342 | 435 | 21 |
| 18 | do | | 337 | 448 | 25 |

1 Concrete failed before load could be applied.

*Third cycle.*—The test results which are reported in Table 5 indicated that, even under the low-temperature condition obtaining at the Center Market, action would be very slow on the richer mixtures. It was accordingly decided to abandon this method of freezing entirely in favor of some method which would insure a more accelerated action. For this purpose the small ice machine used for the freezing tests on the aggregates was employed. The specimens for freezing were prepared by sawing concrete beams which had been stored under earth continuously until this time into prisms, 4 inches in width. This provided specimens 6 by 6 by 4 inches in size, each of which had two sawed faces, exposing the coarse aggregate, three faces which had been in contact with the form and one face which was the surface of the original beam as molded. The specimens were sawed with a large circular saw set with carborundum teeth. Four specimens for each aggregate, two of each of the 1:2:4 and 1:1½:3 mixes, were prepared for test. The group of thirty-six 1:2:4 specimens was tested first, the alternations being so arranged that one specimen of each aggregate was freezing while the other was thawing. This provided for the freezing of 18 specimens at one time. The freezing of the 1:1½:3 specimens followed the completion of 200 alternations on the 1:2:4 concretes. The 1:1½:3 specimens were frozen for a total of 130 alternations. Figure 1 illustrates the appearance of the prisms before test. The varied effects of alternate freezing and thawing are shown in Figure 2.

Table 6.—*Relation between soundness of coarse aggregates and resistance of concrete to freezing and thawing. Age at test, approximately 3 years*

| Aggregate No. | Type | Soundness tests on aggregate: Rating by sodium sulphate test (5 cycles) | Soundness tests on aggregate: Rating by freezing test [3] | Freezing and thawing tests on concrete: [1] Mix, 1:1½:3 — Number of alternations at failure[2]: Initial | Final | Coarse aggregate failed | [1] Mix, 1:2:4 — Number of alternations at failure: Initial | Final | Coarse aggregate failed |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | P. ct. | | | P. ct. |
| 1 | Limestone | Sound | Sound (5) | 40 | 100 | 0 | 55 | 90 | 0 |
| 3 | Gravel | do | Unsound (98) | 50 | 90 | 0 | 40 | 65 | 0 |
| 4 | do | Unsound | Unsound (50) | 70 | 110 | 1 | 60 | 110 | 5 |
| 5 | do | Sound | Unsound (98) | 70 | 110 | 0 | 50 | 100 | 0 |
| 6 | do | do | Questionable (40) | 40 | 80 | 0 | 30 | 70 | 0 |
| 7 | Dolomite | do | Sound (0) | 40 | 90 | 0 | 30 | 90 | 0 |
| 8 | Diabase | do | do | 40 | 90 | 0 | 20 | 65 | 0 |
| 9 | Basalt | do | do | 40 | 100 | 0 | 20 | 65 | 0 |
| 10 | Limestone | Unsound | Unsound (60) | 85 | (4) | 5 | 50 | 90 | 5 |
| 11 | Dolomite | do | Sound (5) | 85 | (5) | 10 | 50 | 150 | 10 |
| 12 | Limestone | do | Unsound (100) | 40 | 100 | 100 | 20 | 70 | 100 |
| 13 | Gravel | do | Sound (5) | 40 | (6) | | 35 | 200 | (7) |
| 14 | Dolomite | do | Unsound (80) | 85 | (8) | 50 | 85 | 160 | 20 |
| 16 | Limestone | Sound | Sound (5) | 85 | (9) | 10 | 55 | 160 | 10 |
| 17 | Slag | do | Sound (30) | 40 | 130 | | 22 | 65 | |
| 18 | do | | Questionable (60) | 15 | 80 | | 35 | 65 | |

1 The average water-cement ratio (uncorrected for absorption) was approximately 0.8 for the 1:1½:3 concretes and approximately 1 for the 1:2:4 concretes.
2 Freezing tests on the 1:1½:3 specimens were discontinued at the expiration of 130 alternations.
3 Figures in parentheses indicate percentage of total sample affected at the end of 280 alternations. (See Table 4.)
4 60 per cent disintegrated at 130 alternations.
5 90 per cent disintegrated at 130 alternations.
6 Bottom of specimen frozen in water for 10 alternations. Failure at 110.
7 No quantitative determination. A number of fragments softened.
8 40 per cent disintegrated at 130 alternations.
9 30 per cent disintegrated at 130 alternations.

One complete alternation was accomplished in 24 hours. The time of freezing for each lot was alternated from week to week between 8 hours and 16 hours; that is, during the first week one lot would freeze 8 hours and thaw 16 hours, and the other lot freeze 16 hours and thaw 8 hours. During the second week the lots were reversed so that eventually each specimen averaged 12 hours freezing and 12 hours thawing in each 24-hour cycle.

The position of the prisms in the freezing cans was changed daily. The prisms were placed in the cans in three tiers, three prisms in each tier, arranged so as to have a 1-inch air space surrounding all specimens. Tests for rate of freezing made by means of thermocouples installed at the center of the prism indicated that the temperature of the concrete reached the freezing point approximately one hour after being placed, in the cans. From this point the temperature dropped at the rate of about 9° F. per hour to a minimum of about −4°F., which was maintained until the end of the cycle.

There follows a brief summary of observations taken during the freezing test on the prisms which gives, for each coarse aggregate, an indication of the rate at which disintegration developed, as well as a statement of the general characteristics of the coarse aggregate, its rating by the sodium sulphate soundness test, and the results of direct freezing tests on the aggregate. The data given in this summary are also given in tabular form (Tables 3, 4, and 6) except that tabular results for the concrete freezing tests shown in Table 6 give only the number of alternations at first indication of failure and at final failure. Absorption and abrasion tests on the coarse aggregate are shown in Table 3 and the results of sodium sulphate and freezing and thawing tests on the aggregate in Table 4.

As stated before, there were two prisms for each aggregate and each of the two mixes, 1:2:4 and 1:1½:3. In making the studies on which the summaries which follow are based, both prisms of each group were examined visually and the data given constitute averages for the two.

#### DETAILED OBSERVATIONS ON SODIUM SULPHATE SOUNDNESS AND FREEZING TESTS ON AGGREGATES AND ON FREEZING TESTS OF 1:1½:3 AND 1:2:4 CONCRETE

*Aggregate No. 1. Siliceous limestone from Frederick, Md.*—(*a*) General characteristics: A hard siliceous limestone with a percentage of wear of 4.2 and a low absorption of 0.10. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on the aggregate: At 21 alternations about 5 per cent of sample showed failure by splitting along cleavage lines on planes of weakness. No further action at the end of 280 alternations. Rated as sound by freezing test. (*d*) Freezing tests on concrete: Tops and sides of prisms began to scale at about 40 alternations in the case of the 1:1½:3 prisms and at about 55 alternations in the case of the 1:2:4 prisms. The 1:2:4 prisms completely disintegrated at the end of 90 alternations. The 1:1½:3 prisms disintegrated at 100 alternations. Failure due in both cases to expansion of mortar on freezing, causing splitting and disintegration of concrete. Coarse aggregate entirely unaffected. Disintegration of the 1:1½:3 prisms seemed to progress somewhat faster in certain stages than that of the 1:2:4 specimens, although difference in behavior was not marked.

*Aggregate No. 3. Gravel from Wateree, Richland County, S. C.*—(*a*) General characteristics: A gravel consisting essentially of very soft, friable fragments of sandstone and so-called sugary quartz. Sample showed a percentage of wear of 32.6 by modified Deval test and an absorption of 0.58. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on the aggregate: Softening of individual pieces of sandstone noted at 10 alternations. Ninety-five per cent of sample affected at 40 alternations. About 2 per cent sound at the end of 280 alternations. Rated as unsound by freezing test. (*d*) Freezing tests on concrete: Top and sides of 1:2:4 prisms began to scale at about 40 alternations. Corners and edges of 1:1½:3 prisms began to spall at about 50 alternations. 1:2:4 prisms 50 per cent disintegrated in 50 alternations and completely disintegrated in 65 alternations. The 1:1½:3 prisms were somewhat more resistant, total failure occurring at 90 alternations. In neither case was the coarse aggregate affected in any way. Failure occurred through softening of mortar, followed by loosening of the bond between the mortar and the coarse aggregate.

*Aggregate No. 4. Gravel from Allegheny River, near Pittsburgh, Pa.*—(*a*) General characteristics: Gravel consisting of rounded fragments of sandstone with some quartz. Percentage of wear, modified Deval test, 12.3; absorption 1.21. (*b*) Sodium sulphate test: Unsound. (*c*) Freezing test on the aggregate: Softening of some of the sandstone fragments noted at 21 alternations. Action progressive from that point with about 50 per cent of entire sample affected at 230 alternations. Very little further action at 280 alternations. Large pieces of sandstone weathered slightly on surface but did not soften or crack. Rated as unsound in freezing test. (*d*) Freezing tests on the concrete: First failure in 1:2:4 prisms noted at about 60 alternations and in 1:1½:3 prisms at about 70 alternations. Top of prism scaled. Corners and edges spalled. Action from this point progressed up to total failure of both sets at approximately 110 alternations. A very small percentage of the coarse aggregate (1 to 5 per cent) affected. Failure due to softening of mortar and loosening of bond between mortar and coarse aggregate.

*Aggregate No. 5. Gravel from Millville, N. J.*—(*a*) General characteristics: Gravel consisting essentially of rounded fragments of sugary quartz, very friable. Percentage of wear, 27.6 by modified Deval test. Absorption, 0.51 per cent. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on aggregate: First failure at 10 alternations, 95 per cent total sample affected at 40 alternations, 98 per cent at 280 alternations. Rated as unsound in freezing test. (*d*) First failure on 1:2:4 prisms at about 50 alternations, on 1:1½:3 prisms at about 70 alternations. Corners spalling; tops of 1:2:4 prisms scaling. 1:2:4 prisms about 25 per cent disintegrated at 90 alternations and completely disintegrated at 100 alternations. 1:1½:3 prisms about 10 per cent disintegrated at 80 alternations and 100 per cent disintegrated at 110 alternations. Action somewhat slower on richer concrete. Mortar failure in both cases. No action on coarse aggregate.


Silicious Limestone — Gravel Containing Quartz, Chert, Gneiss, Schist, and Sandstone — Sandstone Gravel

Diabase — Argillaceous Limestone — Gravel Containing Dolomite, Limestone, Chert, Granite, and Shale

Figure 1.—Examples of Concrete Prisms Used in Freezing Tests, Showing Sawed Surface With Aggregate Exposed. Numbers Correspond With Those Given in Table 3

*Aggregate No. 6. Gravel from North Wilbraham, Mass.*—(*a*) General characteristics: Glacial gravel consisting essentially of rounded fragments of quartz, quartzite, schist, and gneiss. Percentage of wear 18.3 by modified Deval test. Absorption 0.45 per cent. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on aggregate: First evidence of failure at 21 alternations, slight softening of surface of some fragments. At 80 alternations about 40 per cent of entire sample affected. No further action at 280 alternations. Rated as of questionable soundness by freezing test. (*d*) Freezing test on concrete: Top of 1:2:4 prisms scaling at corners and spalling at 30 alternations. Corners and edges of 1:1½:3 prisms spalling at 40 alternations. Progressive failure on both sets resulting in total failure of 1:2:4 prisms at 70 alternations and total failure of 1:1½:3 prisms at 80 alternations. No action on coarse aggregate, failure being due to disintegration of mortar.

*Aggregate No. 7. Dolomite from Forest, Ohio.*—(*a*) General characteristics: Dolomite, uniform in color, hardness, and composition. Percentage of wear, 9; absorption, 1.36. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on aggregate: No action to 280 alternations. (*d*) Freezing test on concrete: Top of 1:2:4 prisms scaling with corners and sides spalling at 30 alternations. Similar action on 1:1½:3 prisms at 40 alternations, except that top did not scale. Both sets completely disintegrated at 90 alternations. No action on coarse aggregate. Mortar softened between particles of coarse aggregate. Bond between mortar and coarse aggregate, however, did not fail, as mortar continued to adhere to surface of coarse aggregate even after failure of prisms.

*Aggregate No. 8. Diabase (trap) from New Haven, Conn.*—(*a*) General characteristics: Diabase, uniform in color, hardness, and composition. Percentage of wear, 2.8; absorption, 0.20. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on aggregate: No action in 280 alternations. (*d*) Freezing test on concrete: First signs of failure in 1:2:4 prisms at 20 alternations, followed by rapid progressive disintegration. Ninety per cent disintegrated at 50 alternations and completely disintegrated at 65 alternations. Action on 1:1½:3 prisms started at 40 alternations with 90 per cent disintegrated at 80 alternations followed by complete failure at 90 alternations. No action on coarse aggregate. Bond between mortar and coarse aggregate loosened.

*Aggregate No. 9. Basalt (trap) from Bound Brook, N. J.*—(*a*) General characteristics: Basalt of uniform color, hardness, and composition. Percentage of wear, 2; absorption, 0.10 per cent. (*b*) Sodium suphate test: Sound. (*c*) Freezing test on aggregate: No action in 280 alternations. (*d*) Freezing test on concrete: Initial failure of 1:2:4 prisms at 20 alternations, followed by progressive action, with 90 per cent disintegration at 55 alternations and 100 per cent disintegration at 65 alternations. The 1:1½:3 prisms showed initial failure at 40 alternations, with 90 per cent disintegration at 85 alternations and 100 per cent disintegration at 100 alternations. Mortar softened and loosened from coarse aggregate, which was unaffected. Behavior almost identical with that observed in case of aggregate No. 8.

*Aggregate No. 10. Limestone from Bucyrus, Ohio.*—(*a*) General characteristics: Limestone varying considerably in quality, ranging from argillaceous with percentage of wear equaling 3.6 and absorption of 0.59 to white crystalline with percentage of wear equaling 7 and absorption 2.65 per cent. Argillaceous material approximately 50 per cent of total. (*b*) Sodium sulphate test: Unsound. (*c*) Freezing test on aggregate: Several particles disintegrated at 21 alternations; 30 per cent softened at 80 alternations and 60 per cent at 280 alternations. The argillaceous material completely disintegrated, with white crystalline fraction weakened. Rated as unsound in freezing test. (*d*) Freezing test on concrete: First failure of 1:2:4 prism at 50 alternations; sides and top scaling. This was followed by rapid progressive failure so that 90 per cent was disintegrated at 70 alternations and 100 per cent at 90 alternations. The action on the 1:1½:3 prism was somewhat slower, initial scaling and spalling not being noted until after 85 alternations. Sixty per cent of prisms had disintegrated at 130 alternations. About 5 per cent of coarse aggregate (argillaceous) affected. Failure due to softening of mortar. Mortar still adhered to particles of coarse aggregate, indicating good bond.

*Aggregate No. 11. Dolomite from Thornton, Ill.*—(*a*) General characteristics: Dolomite. Percentage of wear 5.3; Absorption, 1.35. About 50 per cent of total sample very porous. Some carbonaceous matter present. (*b*) Sodium sulphate test: Unsound. (*c*) Freezing test on aggregate: Several pieces containing carbonaceous matter softened at end of 21 alternations. No further action at 280 alternations. Rated as sound in freezing test. (*d*) Freezing test on concrete: Initial failure of 1:2:4 prism at about 50 alternations consisting of scaling and surface pitting. Prisms disintegrated 50 per cent at 140 alternations, and 100 per cent at 150 alternations. Mortar failure with good bond, however, between mortar and coarse aggregate. About 10 per cent of aggregate affected. The 1:1½:3 prisms showed first signs of failure (scaling and pitting) at 85 alternations, with 90 per cent prism disintegrated at 130 alternations. Behavior similar to 1:2:4 prisms except that initial action was somewhat delayed.

*Aggregate No. 12. Argillaceous Limestone from St. Paul, Minn.*—(*a*) General characteristics: A dark argillaceous limestone, uniform in color, hardness, and composition. Absorption 1.35 per cent. No value for percentage of wear reported. (*b*) Sodium sulphate test: Unsound. (*c*) Freezing test on aggregate: Indications of surface weathering of individual pieces at 21 alternations; 15 per cent of sample disintegrated at 40 alternations and 100 per cent disintegrated at 80 alternations. Rated as unsound in freezing test. (*d*) Freezing test on concrete: Surface pitting on 1:2:4 prism with softening of exposed coarse aggregate noted at 20 alternations. Prisms 70 per cent disintegrated at 55 alternations and 100 per cent disintegrated at 70 alternations. All coarse aggregate softened to putty-like consistency. Similar action on 1:1½:3 prisms, except that initial action was considerably delayed. Initial failure noted at 40 alternations; prisms 40 per cent disintegrated at 85 alternations and completely disintegrated at 100 alternations. Failure by action on both mortar and coarse aggregate.

*Aggregate No. 13. Gravel from Appleton, Minnesota.*—(*a*) General characteristics: Rounded fragments of dolomite, limestone, chert, granite and shale. Percentage of wear, modified Deval test, 7; absorption 0.49 per cent. (*b*) Sodium sulphate test: Unsound. (*c*) Freezing test on aggregate: Pieces of shale (about 1 per cent of total) disintegrated at 10 alternations. About 5 per cent (schists and sandstone) disintegrated at 21 alternations. No further action to 280 alternations. Rated as sound in freezing test. (*d*) Freezing test on concrete: Initial failure due to popping out of exposed shale fragments from surface. Observed on 1:2:4 prism at 35 alternations; on 1:1½:3 prism at 40 alternations. 1:2:4 prisms 5 per cent disintegrated at 140 alternations and completely disintegrated at 200 alternations. Observations on 1:1½:3 prisms after 40 alternations meaningless because of error in freezing.

*Aggregate No. 14. Dolomite from Monroe, Mich.*—(*a*) General characteristics: Siliceous and argillaceous dolomite with cavities. Thin bedding planes of argillaceous material. Percentage of wear, 7.6; absorption, 2.24. (*b*) Sodium sulphate test: Unsound. (*c*) Freezing test on aggregate: First failure, consisting of softening of argillaceous material, noted at 10 alternations. At 30 alternations 30 per cent of entire sample affected, with 80 per cent affected at 80 alternations. Siliceous dolomite unaffected. No further action to 280 alternations. Rated as unsound by freezing test. (*d*) Freezing test on concrete: Initial failure (scaling and spalling) on both sets of prisms at about 85 alternations. Forty per cent of the 1:2:4 prisms disintegrated at 140 alternations and 25 per cent of the 1:1½:3 prisms disintegrated at 120 alternations. The 1:2:4 prisms completely disintegrated at 160 alternations. Forty per cent of the 1:1½:3 prisms disintegrated at 130 alternations. Unsound particles of coarse aggregate in both prisms disintegrated. From 20 to 50 per cent of the siliceous dolomite was affected.

*Aggregate No. 16. Limestone from Buffalo, N. Y.*—(*a*) General characteristics: Dark gray limestone containing flint. Percentage of wear, 4.2; absorption, 0.08 per cent. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on aggregate: First indication of failure at 80 alternations. About 5 per cent of material spalled along cleavage lines. No further action at 200 alternations. At 280 alternations 50 per cent of sample showed a softening along edges of individual pieces. Rated as sound in freezing test. (*d*) Freezing test on concrete: The 1:2:4 prisms showed scaling on top at about 55 alternations; 10 per cent disintegrated at 90 alternations, with two pieces of exposed chert cracked. Prisms 50 per cent disintegrated at 140 alternations and 100 per cent disintegrated at 160 alternations. Mortar softened. Bond with chert particles broken. Number of chert fragments cracked and split. The 1:1½:3 prisms showed first signs of failure at about 85 alternations (mortar pitting on surface). Prisms were 30 per cent disintegrated at 130 alternations, with particles of chert cracked and split.

*Aggregate No. 17. Blast furnace slag, from Hubbard, Ohio.*—(*a*) General characteristics: A porous blast furnace slag, weight per cubic foot about 70 pounds. Absorption 2.85 per cent. (*b*) Sodium sulphate test: Sound. (*c*) Freezing test on aggregate: First evidence of failure at 21 alternations. At 80 alternations about 10 per cent of sample (the light honeycombed pieces) weakened. At 280 alternations about 30 per cent of particles weakened. Rated as sound in freezing test. (*d*) Freezing test on concrete: The 1:2:4 prisms began scaling at 22 alternations. At 50 alternations about 40 per cent of prisms disintegrated. Prisms 100 per cent disintegrated at 65 alternations. Mortar failure. Coarse aggregate unaffected.

Failure of 1:1½:3 prisms started at 40 alternations. At 80 alternations prisms had disintegrated 10 per cent. Total disintegration at 130 alternations.

*Aggregate No. 18. Blast Furnace slag from Leetonia, Ohio.*—(*a*) General characteristics: Blast furnace slag. Weight per cubic foot approximately 85 pounds. (*b*) Sodium sulphate soundness test not made. (*c*) Freezing test on aggregate: First evidence of failure at 21 alternations. About 1 per cent of total sample (light, porous pieces) weakened. No noticeable further action until 280 alternations, at which examination showed about 60 per cent of sample weakened. Rated as of questionable soundness in freezing test. (*d*) Freezing test on concrete: The 1:2:4 prisms showed

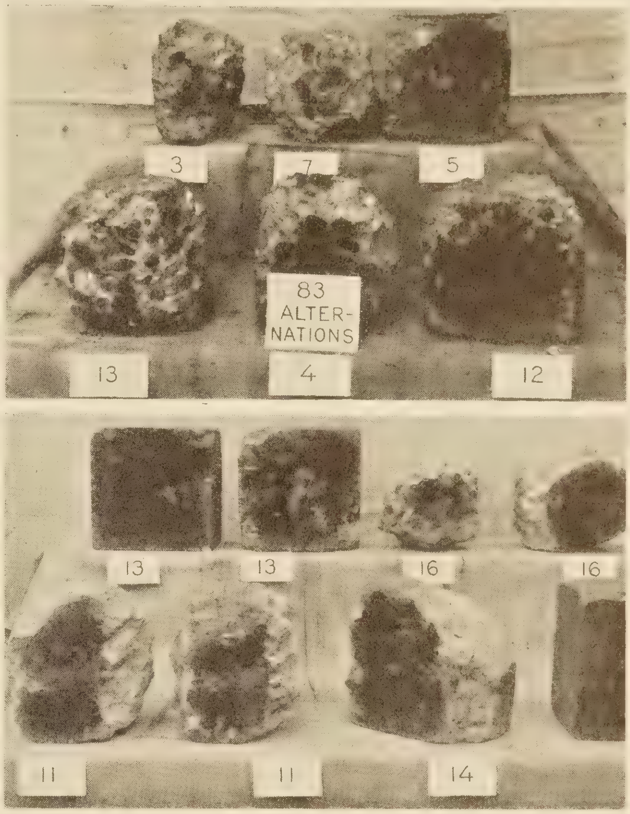


FIGURE 2.—EXAMPLES TYPICAL OF CONCRETE PRISMS AFTER ALTERNATE FREEZING AND THAWING. NUMBERS CORRESPOND WITH THOSE GIVEN IN TABLE 3. PRISMS IN UPPER PHOTOGRAPH, 1:1½:3 MIX AFTER 83 ALTERNATIONS; LOWER PHOTOGRAPH, 1:2:4 MIX AFTER 140 ALTERNATIONS

scaling on top and sides at 35 alternations. Prisms 50 per cent disintegrated at 55 alternations and completely disintegrated at 65 alternations. Mortar failure, although some of the lighter slag fragments were weakened. The 1:1½:3 prisms started pitting and scaling at 15 alternations. Prisms were 100 per cent disintegrated at 80 alternations. A mortar failure, although light honeycombed pieces of slag were affected.

## DISCUSSION

The most interesting fact to be noted from a study of these results is that, in spite of the wide variation in the quality of the coarse aggregate used, failure of the concrete due to freezing and thawing in practically all instances was due to a weakening and consequent breaking down of the mortar portion of the concrete. Although a number of the coarse aggregates were composed of either very soft or friable pieces, or showed unsoundness by the sodium sulphate test, the concretes in which these materials were used were, in general, just as resistant as concrete containing coarse aggregate of known durability. This applied to both the 1:2:4 and the 1:1½:3 mixtures, although a study of the data will show in almost all cases greater resistance in the

1:1½:3 mixes. This is due, no doubt, to the fact that in the richer mixtures the aggregates were incorporated in a paste having a considerably lower water-cement ratio, with consequently increased resistance to frost action.

Included in this series of tests were six aggregates which were rated as unsound in the sodium sulphate test. Two of these were gravels and four limestones. In only one case (aggregate No. 12), an argillaceous limestone, is there any indication that failure may have been accelerated by the character of the coarse aggregate. However, even in this case as many alternations were required to disintegrate the concrete as were necessary in the case of the concrete containing the trap rock aggregates, Nos. 8 and 9, both of which were of unquestioned soundness. Aggregate No. 14, which was also an argillaceous material, showed up very well in cycle No. 3, although the 1:3:6 specimens containing this aggregate were very badly affected as evidenced by the failure of the beams in cycle No. 2 to stand any appreciable load. (See Table 5.) This is an apparent reversal in behavior which it is rather difficult to explain. It is of course possible that the specimens had become weakened through action on the coarse aggregate some time before actual disintegration took place. It is interesting to note, however, that no evidence whatever of weathering (that is, surface scaling, pitting, etc.), which in most cases appeared at about 40 alternations, was observed until 85 alternations had been made. This would certainly indicate that the unsoundness noted in this particular aggregate was not accompanied by appreciable volume change, such as occurs when certain varieties of chert are subjected to frost action.

Gravels No. 3 and No. 5 are of interest because they represent a certain type of very friable quartz gravel known as sugary quartz which occurs along the Atlantic seaboard. Because of their extreme friability the use of these aggregates has been questioned by many engineers. These tests indicate that, although the aggregates failed in a direct freezing test, they were not of such a character as to cause unsoundness in the concrete. The same is true of aggregate No. 4, from the Allegheny River, near Pittsburgh. Although showing unsound in the sodium sulphate test, this unsoundness did not apparently contribute in any way to the failure of the 1:1½:3 or 1:2:4 concrete prisms. With the possible exception of aggregate No. 12, this seemed to be true also of all of the other aggregates which were rated as unsound in the sodium sulphate test. Here again, this particular behavior is due probably to the fact that in none of these cases did unsoundness manifest itself by violent volume change in the coarse aggregate. The results indicate that where the type of material is such that weathering produces merely a softening of the fragments, unaccompanied by volume change, the ultimate behavior of the concrete will be controlled largely by the quality of the cement matrix, rather than by the quality of the aggregate. It should be remembered that no attempt was made to include manifestly unsatisfactory materials, such as shale, in this series of tests. The idea was rather to include a number of so-called border-line materials—materials which are frequently rejected because of failure to meet some arbitrary laboratory test but concerning the real value of which we have little data.

In this connection it is of interest to call attention to the results which were secured on aggregate No. 15, a cherty limestone from Quincy, Ill. These results, as well as those for aggregate No. 2, Potomac River gravel, were not included in Tables 5 and 6 because a different cement was used in making up the concrete and direct comparisons are therefore not possible. However, observations of the concrete prisms containing aggregate No. 15 indicated beyond doubt that disintegration in this particular coarse aggregate was accompanied by volume change. In both prisms the first noticeable action was a popping out of exposed chert particles in a manner similar to that observed in actual service. This action started at five alterations of freezing and thawing. This particular aggregate contained approximately 70 per cent chert by weight.

It is realized that the method of evaluating the results of freezing tests by means of a visual examination of the specimen has many drawbacks. It involves the personal equation to a considerable extent and also fails to express quantitatively any weakening of the concrete due to frost action which is not manifested in actual disintegration. At the time these tests were made, however, the bureau's facilities for conducting freezing tests did not permit of the storing of specimens of sufficient size for strength tests after freezing.

In spite of these objections it is felt that the observations made in connection with this work were sufficiently precise to enable us to draw a reasonably accurate picture of the relative behavior of these specimens in the freezing test. The tests were not extensive enough to warrant drawing definite conclusions. It is believed, however, that certain trends have been indicated with sufficient definiteness to throw some additional light on this particular problem. These indications are as follows:

1. That, within the range in variation of aggregate quality covered by these tests, variations in the quality of mortar caused by changes in the water-cement ratio of the cement paste will have a greater effect upon the resistance of concrete to frost action than will variations in the type and character of the coarse aggregate.

2. That failure of coarse aggregates in the sodium sulphate soundness test is not necessarily an indication that the aggregate is unsatisfactory for use in concrete to be exposed to the weather.

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(Continued from p. 31)

since, of the money so reinvested in productive industry, labor again receives the major part, it is not unreasonable to suggest that as much as 90 per cent and probably more of the original expenditure for a concrete pavement ultimately finds its way into wages and salaries and that this percentage is not greatly changed by the turn of the cycle from prosperity to depression and back again.

# MOTOR-VEHICLE REGISTRATIONS, 1931 [1]

[Compiled for calendar or registration year from reports of State authorities]

| State | 1931 registered motor vehicles individually and commercially owned [2] | | | Other registered vehicles | | Tax-exempt official motor vehicles and motor cycles | | Number of licenses or permits | | 1930 grand total registered motor cars and trucks | Year's change in motor-vehicle registrations; increase, or decrease (−) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grand total registered motor cars and trucks | Passenger automobiles, taxis, and busses [3] | Motor trucks and road tractors | Trailers | Motor cycles | United States, State, and local [4] | Motor cycles (official) | Dealers | Operators and chauffeurs | | Number | Per cent |
| Alabama | 246, 465 | 212, 493 | 33, 972 | 3, 279 | 593 | 1, 036 | | 3, 195 | 2, 153 | 277, 146 | −30, 681 | −11. 1 |
| Arizona | 105, 572 | 92, 939 | 12, 633 | 1, 623 | 379 | 1, 594 | 53 | 127 | 34, 254 | 110, 525 | −4, 953 | −4. 5 |
| Arkansas | 180, 731 | 149, 456 | 31, 275 | 3, 745 | 365 | 389 | | 353 | 4, 150 | 220, 204 | −39, 473 | −17. 9 |
| California | 2, 043, 281 | 1, 798, 068 | 245, 213 | 55, 024 | 8, 970 | 18, 459 | 1, 064 | 3, 269 | | 2, 041, 356 | 1, 925 | . 1 |
| Colorado | 308, 458 | 276, 376 | 32, 082 | 258 | 962 | 283 | | 3, 196 | 6, 255 | 308, 509 | −51 | −. 02 |
| Connecticut | 336, 040 | 284, 081 | 51, 959 | 926 | 2, 097 | 2, 032 | 253 | 2, 747 | 416, 796 | 331, 026 | 5, 014 | 1. 5 |
| Delaware | 55, 202 | 45, 211 | [5] 9, 991 | 517 | 320 | 475 | | 614 | 68, 862 | 56, 109 | −907 | −1. 6 |
| Florida | 323, 260 | 271, 536 | 51, 724 | 6, 751 | 1, 034 | 3, 785 | 131 | 1, 668 | 1, 818 | 327, 801 | −4, 541 | −1. 4 |
| Georgia | 320, 840 | 274, 576 | 46, 264 | 3, 317 | 1, 190 | 934 | | 2, 324 | 3, 544 | 341, 580 | −20, 740 | −6. 1 |
| Idaho | 111, 663 | 96, 228 | 15, 435 | 7, 558 | 357 | 1, 501 | 9 | 352 | 757 | 119, 077 | −7, 414 | −6. 2 |
| Illinois | 1, 612, 770 | 1, 411, 261 | 201, 509 | 9, 283 | 5, 811 | 979 | | 3, 883 | 93, 059 | 1, 638, 260 | −25, 490 | −1. 6 |
| Indiana | 862, 672 | 732, 846 | 129, 826 | 19, 169 | 2, 781 | 9, 066 | | 2, 612 | 164, 011 | 875, 763 | −13, 091 | −1. 5 |
| Iowa | 748, 438 | 670, 024 | 78, 414 | 3, 207 | 1, 705 | 4, 028 | 76 | 1, 834 | 17, 056 | 778, 386 | −29, 948 | −3. 8 |
| Kansas | 559, 176 | 478, 692 | [5] 80, 484 | 1, 778 | 1, 050 | 3, 242 | 38 | 1, 889 | 741, 138 | 594, 523 | −35, 347 | −5. 9 |
| Kentucky | 327, 326 | 292, 357 | 34, 969 | (6) | 804 | 2, 557 | | 841 | 9, 535 | 331, 002 | −3, 676 | −1. 1 |
| Louisiana | 263, 050 | 215, 267 | 47, 783 | 5, 670 | 767 | 209 | | 374 | 22, 852 | 275, 283 | −12, 233 | −4. 4 |
| Maine | 188, 238 | 149, 467 | 38, 771 | 3, 053 | 1, 168 | 1, 828 | 91 | 1, 269 | 231, 201 | 186, 157 | 2, 081 | 1. 1 |
| Maryland | 325, 372 | 289, 292 | 36, 080 | 1, 128 | 1, 739 | 1, 969 | | 5, 575 | 80, 748 | 321, 702 | 3, 670 | 1. 1 |
| Massachusetts | 840, 190 | 736, 302 | 103, 888 | 650 | 3, 068 | 1, 756 | | 3, 360 | 1, 024, 304 | 846, 206 | −6, 016 | −. 7 |
| Michigan | 1, 230, 980 | 1, 078, 345 | [5] 152, 635 | 61, 932 | 3, 236 | 371 | | 1, 718 | | 1, 328, 209 | −97, 229 | −7. 3 |
| Minnesota | 720, 401 | 611, 966 | 108, 435 | 18, 291 | 1, 749 | 1, 285 | | 2, 034 | 47, 659 | 732, 972 | −12, 571 | −1. 7 |
| Mississippi | 183, 650 | 152, 929 | [5] 30, 721 | 2, 560 | 180 | 74 | | 2, 555 | | 237, 094 | −53, 444 | −22. 5 |
| Missouri | 752, 805 | 656, 830 | [5] 95, 975 | 5, 469 | 1, 655 | 2, 253 | 17 | 2, 075 | 34, 405 | 761, 600 | −8, 795 | −1. 2 |
| Montana | 127, 166 | 103, 129 | [5] 24, 037 | 59 | 216 | 1, 647 | 7 | 544 | 311 | 135, 168 | −8, 002 | −5. 9 |
| Nebraska | 416, 131 | 356, 283 | 59, 848 | 15, 737 | 897 | 1, 832 | | 2, 797 | | 426, 229 | −10, 098 | −2. 4 |
| Nevada | 32, 168 | 25, 218 | 6, 950 | 411 | 75 | 556 | | 87 | | 29, 645 | 2, 523 | 8. 5 |
| New Hampshire | 111, 510 | 92, 839 | 18, 671 | 1, 137 | 1, 019 | 428 | 44 | 491 | 129, 728 | 112, 183 | −673 | −. 6 |
| New Jersey | 869, 867 | 736, 506 | 133, 361 | 2, 916 | 5, 738 | 8, 708 | | 3, 055 | 1, 063, 073 | 852, 850 | 17, 017 | 2. 0 |
| New Mexico | 81, 325 | 65, 441 | 15, 884 | 778 | 218 | 736 | | 125 | | 84, 150 | −2, 825 | −3. 4 |
| New York | 2, 297, 249 | 1, 966, 436 | 330, 813 | 12, 596 | 12, 521 | 22, 357 | 1, 185 | 4, 996 | 3, 067, 853 | 2, 307, 730 | −10, 481 | −. 5 |
| North Carolina | 428, 737 | 374, 162 | 54, 575 | 8, 118 | 1, 245 | 8, 429 | | 4, 348 | | 453, 241 | −24, 504 | −5. 4 |
| North Dakota | 171, 293 | 144, 705 | 26, 588 | (7) | 229 | 3 | | 427 | | 183, 019 | −11, 726 | −6. 4 |
| Ohio | 1, 710, 625 | 1, 518, 696 | [5] 191, 929 | 32, 717 | 6, 395 | 14, 666 | | 3, 416 | 2, 279 | 1, 759, 363 | −48, 738 | −2. 8 |
| Oklahoma | 482, 725 | 428, 140 | 54, 585 | (7) | 1, 200 | 530 | | | | 550, 331 | −67, 606 | −12. 3 |
| Oregon [8] | 278, 225 | 255, 275 | 22, 950 | 2, 167 | 1, 691 | 2, 768 | | 508 | 52, 637 | [9] 273, 625 | 4, 600 | 1. 7 |
| Pennsylvania | 1, 741, 942 | 1, 522, 130 | 219, 812 | 6, 308 | 11, 778 | 2, 640 | 393 | 10, 255 | 2, 214, 008 | 1, 753, 521 | −11, 579 | −. 7 |
| Rhode Island | 137, 878 | 118, 313 | 19, 565 | 64 | 775 | 979 | 112 | 314 | 164, 784 | 136, 423 | 1, 455 | 1. 1 |
| South Carolina | 203, 719 | 180, 280 | 23, 439 | 2, 100 | 492 | 3, 515 | 84 | 537 | 39, 139 | 218, 402 | −14, 683 | −6. 7 |
| South Dakota | 193, 025 | 169, 509 | 23, 516 | 4, 994 | 283 | 1, 098 | 11 | 710 | | 205, 172 | −12, 147 | −5. 9 |
| Tennessee | 350, 520 | 316, 544 | 33, 976 | 2, 696 | 1, 285 | 5, 852 | 100 | 545 | | 368, 259 | −17, 739 | −4. 8 |
| Texas | 1, 297, 301 | 1, 086, 310 | 210, 991 | 33, 861 | 3, 727 | 2, 505 | | 3, 252 | 43, 659 | 1, 365, 896 | −68, 595 | −5. 0 |
| Utah | 108, 958 | 91, 381 | 17, 577 | 767 | 478 | 1, 373 | | 300 | | 113, 997 | −5, 039 | −4. 4 |
| Vermont | 83, 877 | 75, 424 | 8, 453 | 457 | 502 | 28 | | 318 | 98, 184 | 86, 624 | −2, 747 | −3. 2 |
| Virginia | 379, 227 | 322, 594 | 56, 633 | 1, 582 | 2, 134 | 4, 868 | 154 | 3, 828 | 14, 550 | 375, 889 | 3, 338 | . 9 |
| Washington | 420, 878 | 360, 796 | 60, 082 | 3, 000 | 1, 696 | 6, 764 | 1, 696 | 3, 383 | | 446, 062 | −25, 184 | −5. 6 |
| West Virginia | 253, 308 | 213, 949 | 39, 359 | 1, 270 | 1, 190 | 2, 619 | 113 | 8, 507 | 48, 358 | 266, 273 | −12, 965 | −4. 9 |
| Wisconsin | 754, 249 | 640, 476 | 113, 773 | 1, 007 | 2, 316 | 5, 657 | 289 | 2, 678 | | 782, 562 | −28, 313 | −3. 6 |
| Wyoming | 62, 101 | 51, 388 | 10, 713 | (7) | 114 | 622 | | 320 | | 61, 501 | 600 | 1. 0 |
| District of Columbia | 173, 519 | 155, 334 | 18, 185 | (7) | 880 | 3, 106 | 110 | 1, 758 | 42, 087 | 156, 676 | 16, 843 | 10. 8 |
| Total | 25, 814, 103 | 22, 347, 800 | 3, 466, 303 | 349, 930 | 101, 074 | [10] 172, 250 | 6, 030 | 105, 363 | 9, 985, 207 | [11] 26, 545, 281 | −731, 178 | −2. 8 |

[1] This table lists only the number of registrations, licenses, and permits; for financial statement see p. 40.
[2] The first 3 columns show regularly registered motor cars and trucks, eliminating reregistrations, non-resident registrations, etc.
[3] Busses are included with passenger cars, except as noted in next column.
[4] These official cars are exempted from paying regular registration fees and are excluded from registered motor vehicles.
[5] Busses included with trucks.
[6] Classified with trucks.
[7] Not registered.
[8] Registrations during year ending June 30, 1931.
[9] For comparative purposes the figure 252,123 published in 1930 table, which covered a 6-month registration period, is changed to cover a 12-month period, ending June 30, 1930.
[10] Includes 7,859 cars at large owned by United States Government, not allocated to any State.
[11] See note 9 explaining change from previously reported figure.

# MOTOR VEHICLE REGISTRATION FEES, LICENSES, PERMITS, FINES, ETC., 1931[1]

[Compiled for calendar or registration year from reports of State authorities]

| State [2] | Total gross receipts | Registration receipts [2]: Motor-car receipts: Total motor cars | Registration receipts [2]: Motor-car receipts: Passenger cars and busses | Registration receipts [2]: Motor-car receipts: Trucks and tractors | Registration receipts [2]: Other vehicles: Trailers | Registration receipts [2]: Other vehicles: Motor cycles | Miscellaneous receipts [2]: Dealers, licenses | Miscellaneous receipts [2]: Chauffeur and operator permits | Miscellaneous receipts [2]: Other miscellaneous | Disposition of gross receipts: Collection and administration [3] | Disposition: For highway purposes: State highways | Disposition: For highway purposes: Local roads | Disposition: For highway purposes: State and county road bonds [4] | Disposition: For other purposes | State [2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama [2] | $3,379,392 | | | | | | | | | $138,793 | $1,185,848 | $604,674 | $1,450,077 | | Alabama. |
| Arizona | 767,508 | $588,321 | $340,110 | $248,211 | $18,421 | $1,326 | $1,016 | $26,370 | $132,054 | 190,092 | 577,416 | | | | Arizona. |
| Arkansas | 3,495,545 | 3,420,133 | | | | | 35,300 | 20,750 | 19,362 | | | | [5] 3,495,545 | | Arkansas. |
| California | 9,763,274 | 8,531,179 | 6,184,141 | 2,347,038 | 332,081 | 31,815 | 42,573 | 183,484 | 642,142 | 1,345,908 | 3,334,032 | 3,334,031 | | [6] $1,749,303 | California. |
| Colorado | 1,910,741 | 1,807,783 | 1,401,858 | 405,925 | 3,025 | 1,684 | 24,798 | 12,480 | 60,971 | 163,315 | 873,713 | 873,713 | | | Colorado. |
| Connecticut | 8,259,542 | 6,375,865 | 4,928,198 | 1,447,667 | 20,242 | 9,670 | 84,488 | 1,256,569 | 512,708 | 719,000 | 7,540,542 | | | | Connecticut. |
| Delaware | 1,043,173 | 886,355 | 639,876 | 246,479 | 5,851 | 1,080 | 7,078 | 103,739 | 39,070 | | 504,993 | | [7] 538,180 | | Delaware. |
| Florida | 4,851,968 | 4,761,161 | 3,570,994 | 1,190,167 | 38,621 | 5,137 | 21,212 | 3,436 | 22,401 | 292,439 | 4,128,094 | 216,074 | | [8] 215,361 | Florida. |
| Georgia | 4,256,553 | 4,181,604 | 3,376,924 | 804,680 | 26,958 | 5,256 | 25,661 | 6,876 | 10,198 | 211,282 | 4,045,271 | | | | Georgia. |
| Idaho | 1,909,363 | 1,861,024 | 1,462,641 | 398,383 | 8,990 | 1,785 | 20,895 | 1,514 | 15,155 | 57,281 | 179,652 | 1,672,430 | | | Idaho. |
| Illinois | 18,426,497 | 17,411,795 | 12,932,936 | 4,478,859 | 194,692 | 18,567 | 72,400 | 309,713 | 419,330 | | 10,531,277 | | 7,895,220 | | Illinois. |
| Indiana | 6,332,101 | 5,990,293 | 4,535,504 | 1,454,789 | 92,677 | 4,824 | 51,650 | 41,003 | 151,654 | 357,172 | 5,974,929 | | | | Indiana. |
| Iowa | 12,539,613 | 11,812,357 | 9,968,137 | 1,844,220 | 31,497 | 6,014 | 68,300 | 34,113 | 587,332 | 373,768 | 11,789,170 | | | [9] 376,675 | Iowa. |
| Kansas [2] | 6,059,910 | 5,809,511 | | | | | | 226,645 | 23,754 | 390,900 | 3,869,010 | 1,800,000 | | | Kansas. |
| Kentucky | 4,842,108 | 4,649,430 | 3,400,792 | 1,248,638 | | 3,636 | 24,124 | 34,639 | 130,279 | 469,786 | 3,756,746 | 615,576 | | | Kentucky. |
| Louisiana | 4,549,244 | 4,295,275 | 3,233,243 | 1,062,032 | 148,838 | 4,190 | 24,683 | 68,953 | 7,305 | 50,000 | 4,159,744 | | 339,500 | | Louisiana. |
| Maine [10] | 3,184,091 | 2,471,345 | 1,837,314 | 634,031 | 8,984 | 5,862 | 50,342 | 508,453 | 139,105 | 337,255 | 1,362,040 | | 1,333,523 | [11] 151,273 | Maine. |
| Maryland | 3,497,807 | 2,663,813 | 2,304,518 | 359,295 | 29,294 | 9,918 | 28,089 | 210,704 | 555,989 | 349,781 | 2,518,421 | | | [12] 629,605 | Maryland. |
| Massachusetts | 7,000,306 | 4,017,860 | 2,769,618 | 1,248,242 | 34,928 | 4,172 | 9,999 | 2,048,608 | 884,739 | 1,580,903 | 4,737,296 | | 682,107 | | Massachusetts. |
| Michigan | 21,821,290 | 19,592,989 | 15,167,237 | 4,425,752 | 427,899 | 12,652 | 76,946 | 899,329 | 811,475 | 1,064,847 | 13,041,324 | 6,000,000 | 1,082,060 | [11] 633,059 | Michigan. |
| Minnesota | 10,784,845 | 10,612,233 | 8,610,041 | 2,002,192 | 53,256 | 6,192 | 31,108 | 53,968 | 28,088 | 400,000 | 4,785,823 | | [13] 5,536,652 | [14] 62,370 | Minnesota. |
| Mississippi [2] | 2,421,287 | | | | | | | | | 164,322 | 153,099 | 2,103,866 | | | Mississippi. |
| Missouri [2] | 10,140,429 | | | | | | | | | 527,132 | 5,331,647 | | 4,281,650 | | Missouri. |
| Montana | 1,499,492 | 1,434,255 | 1,147,545 | 286,710 | 262 | 843 | 28,310 | 622 | | 32,144 | | 1,467,348 | | | Montana. |
| Nebraska | 3,742,401 | 3,598,845 | 3,049,995 | 548,850 | 16,418 | 2,883 | 37,439 | | 86,816 | 114,794 | 1,088,282 | 2,539,325 | | | Nebraska. |
| Nevada | 388,327 | 367,119 | 272,759 | 94,360 | 2,826 | 311 | 2,800 | | 15,271 | 43,089 | 180,750 | | 164,488 | | Nevada. |
| New Hampshire [2] | 2,257,459 | | | | | 5,388 | 25,740 | 300,062 | 83,657 | 201,113 | 2,056,346 | | | | New Hampshire. |
| New Jersey | 15,891,204 | 11,645,139 | 7,554,750 | 4,090,389 | 115,462 | 11,476 | 76,375 | 3,177,941 | 864,811 | 1,125,694 | 7,229,510 | 7,310,000 | | [15] 226,000 | New Jersey. |
| New Mexico | 1,248,097 | 1,207,916 | 902,830 | 305,086 | 5,675 | 716 | 7,287 | | 25,565 | 98,917 | 689,508 | 459,672 | | | New Mexico. |
| New York | 41,877,611 | 36,940,089 | 26,642,478 | 10,297,611 | 178,421 | 51,920 | 214,705 | 3,031,017 | 1,461,459 | [16] 937,211 | 30,777,359 | 6,099,597 | | [17] 4,063,444 | New York. |
| North Carolina [2] | 6,164,549 | | | | | | | | | 135,000 | 2,552,000 | | [18] 3,426,749 | [11] 50,800 | North Carolina. |
| North Dakota | 1,799,120 | 1,790,861 | 1,378,228 | 412,633 | | 1,158 | 6,828 | | 273 | 73,015 | 1,019,203 | 706,902 | | | North Dakota. |
| Ohio | 12,818,705 | 12,055,577 | 7,036,551 | 5,019,026 | 284,623 | 15,988 | 68,320 | 6,835 | 387,362 | 496,510 | 6,040,981 | 6,281,214 | | | Ohio. |
| Oklahoma [2] | 5,857,107 | | | | | | | | | 242,466 | 2,249,545 | 3,365,096 | | | Oklahoma. |
| Oregon | 6,940,504 | 6,236,388 | 5,295,744 | 940,644 | 38,598 | 6,173 | 24,688 | 63,483 | 571,174 | 467,478 | 1,492,236 | 1,618,257 | 3,362,533 | | Oregon. |
| Pennsylvania | 31,607,172 | 23,408,066 | 16,083,280 | 7,324,786 | 79,975 | 29,305 | 252,575 | 4,626,040 | 3,211,211 | 3,297,276 | 23,262,534 | | 3,436,513 | [19] 1,610,849 | Pennsylvania. |
| Rhode Island | 2,272,879 | 1,830,204 | 1,358,762 | 471,442 | 2,016 | 3,340 | 14,650 | 329,572 | 93,097 | 266,364 | 1,932,924 | 73,591 | | | Rhode Island. |
| South Carolina | 2,790,008 | 2,505,454 | 2,020,474 | 484,980 | 41,448 | 2,121 | 13,285 | 124,329 | 103,371 | 65,231 | 2,555,093 | | | [20] 169,684 | South Carolina. |
| South Dakota | 2,808,172 | 2,747,209 | 2,313,799 | 433,410 | 7,003 | 970 | 17,650 | | 35,080 | 80,240 | 1,371,696 | 1,356,236 | | | South Dakota. |
| Tennessee [2] | 4,580,685 | | | | | | | | | 86,321 | 2,132,670 | 2,132,670 | | [11] 229,024 | Tennessee. |
| Texas | 13,994,647 | 12,961,446 | 9,075,689 | 3,885,757 | 365,346 | 14,454 | 43,702 | 130,952 | 478,747 | 671,855 | 4,451,194 | 8,871,598 | | | Texas. |
| Utah [2] | 828,303 | | | | | | | | | 67,697 | | | 737,500 | [21] 23,106 | Utah. |
| Vermont | 2,355,913 | 2,031,689 | 1,628,406 | 403,283 | | 3,411 | 26,179 | 248,626 | 46,008 | | 2,355,913 | | | | Vermont. |
| Virginia | 6,159,257 | 5,896,212 | 4,970,890 | 925,322 | 14,181 | 8,001 | 60,500 | 72,750 | 107,613 | 241,409 | 5,730,617 | | | [11] 187,231 | Virginia. |
| Washington | 7,623,570 | 7,034,491 | 5,497,235 | 1,537,256 | 61,457 | 9,212 | 69,170 | 435,491 | 13,749 | 584,290 | 2,183,355 | 4,420,434 | | [11] 435,491 | Washington. |
| West Virginia | 4,519,763 | 4,162,001 | 3,210,870 | 951,131 | 5,535 | 5,180 | 37,803 | 96,237 | 213,007 | 236,908 | 882,855 | | 3,400,000 | | West Virginia. |
| Wisconsin | 11,724,995 | 11,392,171 | 8,592,135 | 2,800,036 | 62,705 | 12,849 | 91,127 | 19,994 | 146,149 | 800,046 | 3,557,461 | 6,121,321 | 1,246,167 | | Wisconsin. |
| Wyoming [2] | 727,667 | | | | | | | | | | 561,667 | | 166,000 | | Wyoming. |
| District of Columbia | 623,460 | 193,330 | 167,404 | 25,926 | | 880 | 1,758 | 126,261 | 301,231 | 139,560 | | | | [22] 736,422 | District of Columbia. |
| Detailed totals | 298,425,321 | 271,178,788 | ([23]) | ([23]) | 2,758,205 | 320,359 | 1,821,553 | 18,841,558 | 13,438,762 | | | | | | Detailed totals. |
| Grand totals | 344,337,654 | | | | | | | | | 19,688,604 | 200,733,786 | 70,043,625 | 42,574,464 | 11,549,697 | Grand totals. |

[1] Financial data only on this table: For number of registrations, etc., see p. 39.
[2] 10 States thus noted do not report complete details, and receipts are not included in "detailed totals."
[3] States for which no figures are shown make state appropriations for administration.
[4] Payments on State bonds except as noted.
[5] Includes payments of $2,239,615 on county road bonds.
[6] Includes $46,310 reserve for refunds, remainder for State highway patrol.
[7] Includes payments of $349,355 on county road bonds.
[8] For county school fund.
[9] For county general funds.
[10] New law April, 1931, created a State highway fund from which appropriations are made. The disposition shown is on old basis from actual expenditures and is set up to compare with previous year.
[11] State highway patrol.
[12] For Baltimore streets.
[13] Includes $5,154,152 payments on county road bonds.
[14] For State general fund.
[15] Includes $201,000 for free bridge commission and $25,000 for traffic commission.
[16] Excludes $1,827,515 appropriation from State general fund.
[17] For New York City general fund.
[18] Includes $971,749 payments on county road bonds.
[19] State highway patrol, $1,070,019, and payment of gasoline tax collection cost, $540,830.
[20] Includes $38,054 reserve fund, remainder for State highway patrol.
[21] Refund reserve.
[22] For signals and streets as appropriated by Congress.
[23] Only 37 States and District of Columbia separate motor vehicle receipts. The detailed totals for these States are as follows: Passenger car and bus registration receipts, $194,863,906, and truck and tractor receipts, $67,085,238.

# ROAD PUBLICATIONS *of the* BUREAU OF PUBLIC ROADS

## *ANNUAL REPORTS*

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
Report of the Chief of the Bureau of Public Roads, 1927.
Report of the Chief of the Bureau of Public Roads, 1928.
Report of the Chief of the Bureau of Public Roads, 1929.

## *DEPARTMENT BULLETINS*

*No. 136D . . Highway Bonds. 20 cents.

*No. 347D . . Methods for the Determination of the Physical Properties of Road-Building Rock. 10 cents.

*No. 532D . . The Expansion and Contraction of Concrete and Concrete Roads. 10 cents.

*No. 583D . . Reports on Experimental Convict Road Camp, Fulton County, Ga. 25 cents.

*No. 660D . . Highway Cost Keeping. 10 cents.

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922.

No. 1486D . . Highway Bridge Location.

## *TECHNICAL BULLETINS*

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No. 265T . . Electrical Equipment on Movable Bridges.

## *SEPARATE REPRINT FROM THE YEARBOOK*

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

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*No. 93MC . . Direct Production Costs of Broken Stone. 25c.

No. 109MC . . Federal Legislation and Regulations Relating to the Improvement of Federal-Aid Roads and National-Forest Roads and Trails, Flood Relief, and Miscellaneous Matters.

## *MISCELLANEOUS PUBLICATION*

No. 76MP . . The Results of Physical Tests of Road-Building Rock.

## *TRANSPORTATION SURVEY REPORTS*

Report of a Survey of Transportation on the State Highway System of Ohio. (1927.)

Report of a Survey of Transportation on the State Highways of Vermont. (1927.)

Report of a Survey of Transportation on the State Highways of New Hampshire. (1927.)

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio. (1928.)

Report of a Survey of Transportation on the State Highways of Pennsylvania. (1928.)

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States. (1930.)

## *REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH*

Vol. 5, No. 17, D- 2 . . Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements.

Vol. 5, No. 19, D- 3 . . Relation Between Properties of Hardness and Toughness of Road-Building Rock.

Vol. 5, No. 24, D- 6 . . A New Penetration Needle for Use in Testing Bituminous Materials.

Vol. 11, No. 10, D-15 . . Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

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▼ ▼ ▼

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

# CURRENT STATUS OF FEDERAL-AID ROAD CONSTRUCTION

AS OF

## MARCH 31, 1932

| STATE | COMPLETED MILEAGE | UNDER CONSTRUCTION | | | | | APPROVED FOR CONSTRUCTION | | | | | BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS | STATE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimated total cost | Federal-aid allotted | MILEAGE | | | Estimated total cost | Federal-aid allotted | MILEAGE | | | | |
| | | | | Initial | Stage[1] | Total | | | Initial | Stage[1] | Total | | |
| Alabama | 2,379.5 | $ 2,008,496.70 | $ 982,352.29 | 88.4 | | 88.4 | $ | $ | | | | $ 5,455,698.02 | Alabama |
| Arizona | 1,198.6 | 2,461,045.74 | 1,732,496.12 | 148.5 | 21.6 | 170.1 | 54,912.91 | 41,343.92 | 5.4 | | 5.4 | 1,501,293.55 | Arizona |
| Arkansas | 1,940.3 | 3,089,330.65 | 1,445,224.82 | 73.8 | 61.1 | 134.9 | 362,032.53 | 151,016.26 | 17.3 | | 17.3 | 2,065,661.91 | Arkansas |
| California | 2,291.6 | 10,179,792.17 | 4,695,286.79 | 215.2 | 38.7 | 253.9 | 1,082,442.40 | 581,339.71 | 33.8 | | 33.8 | 1,184,664.55 | California |
| Colorado | 1,544.4 | 4,723,831.84 | 2,485,540.30 | 207.4 | 59.4 | 266.8 | 324,036.30 | 156,005.25 | 14.2 | | 14.2 | 2,064,397.14 | Colorado |
| Connecticut | 288.5 | 3,084,244.77 | 1,151,757.90 | 22.9 | | 22.9 | | | | | | 713,252.14 | Connecticut |
| Delaware | 361.6 | 513,658.00 | 256,829.00 | 22.6 | | 22.6 | 205,355.25 | 102,677.62 | 11.3 | 2.5 | 13.8 | 290,727.07 | Delaware |
| Florida | 617.5 | 4,244,486.83 | 1,941,328.68 | 111.3 | | 111.3 | | | | | | 2,995,837.56 | Florida |
| Georgia | 3,075.7 | 5,765,219.67 | 2,669,967.14 | 118.9 | 155.1 | 274.0 | 416,776.79 | 208,388.37 | 24.1 | 3.4 | 27.5 | 1,998,394.93 | Georgia |
| Idaho | 1,485.3 | 1,836,334.71 | 1,065,492.50 | 89.9 | 80.3 | 170.2 | 423,250.54 | 255,284.28 | 26.3 | 8.8 | 35.1 | 1,261,340.62 | Idaho |
| Illinois | 2,625.9 | 24,420,578.64 | 11,452,862.33 | 730.8 | 28.7 | 759.5 | 4,029,140.06 | 1,636,075.76 | 124.9 | 12.8 | 137.7 | 1,964,464.74 | Illinois |
| Indiana | 1,788.4 | 7,848,719.10 | 3,853,212.26 | 208.5 | | 208.5 | 5,027,471.13 | 2,390,984.64 | 204.3 | 7.3 | 211.6 | 551,260.01 | Indiana |
| Iowa | 3,390.6 | | | | | | 3,276,741.46 | 1,523,662.43 | 155.7 | 42.2 | 197.9 | 1,276,142.77 | Iowa |
| Kansas | 3,681.9 | 3,472,112.65 | 1,633,968.53 | 204.4 | 14.5 | 218.9 | 3,088,558.94 | 1,512,148.59 | 175.9 | 121.6 | 297.5 | 1,201,185.84 | Kansas |
| Kentucky | 1,848.5 | 2,908,041.18 | 1,347,135.94 | 161.0 | 4.0 | 165.0 | 452,589.05 | 223,754.67 | 8.3 | 34.8 | 43.1 | 1,710,447.10 | Kentucky |
| Louisiana | 1,541.7 | 7,160,318.63 | 2,775,796.03 | 112.3 | 10.6 | 122.9 | 956,563.32 | 478,281.66 | .5 | | .5 | 1,263,322.55 | Louisiana |
| Maine | 706.0 | 1,804,346.15 | 789,080.76 | 31.4 | | 31.4 | 1,999,657.70 | 823,804.29 | 63.5 | | 63.5 | 513,407.53 | Maine |
| Maryland | 776.8 | 269,787.15 | 63,776.89 | 6.3 | | 6.3 | 586,909.20 | 292,571.66 | 25.7 | | 25.7 | 627,960.27 | Maryland |
| Massachusetts | 814.8 | 7,521,359.24 | 3,084,570.72 | 66.8 | .2 | 67.0 | | | | | | 688,428.07 | Massachusetts |
| Michigan | 1,986.7 | 9,930,797.55 | 4,495,918.60 | 403.0 | 62.5 | 465.5 | 550,262.90 | 183,660.37 | 25.3 | 6.1 | 31.4 | 3,105,104.38 | Michigan |
| Minnesota | 4,179.6 | 2,869,940.52 | 975,961.40 | 48.3 | 77.5 | 125.8 | 7,343,177.40 | 2,375,809.81 | 165.2 | 182.2 | 347.4 | 476,538.62 | Minnesota |
| Mississippi | 1,792.7 | 4,130,076.48 | 2,028,622.40 | 169.8 | 77.6 | 247.4 | 103,524.13 | 51,762.05 | 9.5 | | 9.5 | 5,327,002.36 | Mississippi |
| Missouri | 2,961.3 | 2,860,763.74 | 1,200,594.50 | 65.6 | 3.4 | 69.0 | 4,294,187.18 | 1,910,628.60 | 133.5 | 53.8 | 187.3 | 1,613,641.14 | Missouri |
| Montana | 2,673.0 | 4,574,097.77 | 2,571,441.21 | 392.4 | 17.6 | 410.0 | 454,085.69 | 253,059.57 | 61.4 | .5 | 61.9 | 3,483,976.64 | Montana |
| Nebraska | 4,145.7 | 4,960,841.08 | 2,426,721.22 | 207.1 | 76.6 | 283.7 | 341,832.91 | 170,752.29 | 13.9 | | 13.9 | 2,584,028.10 | Nebraska |
| Nevada | 1,342.3 | 1,329,619.67 | 1,025,174.22 | 38.7 | 84.9 | 123.6 | 590,797.54 | 524,748.49 | | 55.6 | 55.6 | 753,719.43 | Nevada |
| New Hampshire | 418.4 | 636,114.46 | 246,912.44 | 12.1 | 2.5 | 14.6 | | | | | | 553,268.42 | New Hampshire |
| New Jersey | 603.3 | 3,905,196.02 | 1,538,311.71 | 38.3 | .6 | 38.9 | | | | | | 1,592,129.15 | New Jersey |
| New Mexico | 2,192.0 | 2,356,622.06 | 1,527,394.54 | 122.2 | 16.5 | 138.7 | 1,053,109.73 | 670,732.74 | 41.1 | 7.7 | 48.8 | 862,054.22 | New Mexico |
| New York | 3,262.5 | 11,445,100.00 | 5,288,075.00 | 267.8 | | 267.8 | 5,214,649.00 | 2,035,494.50 | 105.5 | | 105.5 | 3,689,746.95 | New York |
| North Carolina | 2,222.8 | 1,311,744.48 | 632,975.21 | 68.9 | | 68.9 | 170,890.42 | 85,445.20 | 11.3 | 4.0 | 15.3 | 3,830,373.80 | North Carolina |
| North Dakota | 5,117.4 | 1,833,348.18 | 921,286.74 | 170.4 | 171.9 | 342.3 | 1,421,317.33 | 726,174.49 | 176.3 | 259.5 | 435.8 | 2,090,781.50 | North Dakota |
| Ohio | 2,846.1 | 6,559,165.56 | 2,289,708.34 | 98.6 | 18.3 | 116.9 | 950,900.00 | 356,700.06 | 16.4 | 10.0 | 26.4 | 3,978,513.51 | Ohio |
| Oklahoma | 2,230.1 | 4,483,089.78 | 2,137,304.78 | 112.5 | 72.0 | 184.5 | 1,044,116.66 | 516,631.00 | 83.6 | | 83.6 | 2,049,885.75 | Oklahoma |
| Oregon | 1,529.0 | 3,900,721.84 | 2,147,345.18 | 102.0 | 47.1 | 149.1 | 617,548.03 | 381,618.92 | 20.1 | 5.6 | 25.7 | 1,514,493.08 | Oregon |
| Pennsylvania | 3,012.6 | 1,905,156.01 | 773,276.79 | 45.3 | | 45.3 | 2,200,751.13 | 936,470.32 | 66.5 | | 66.5 | 4,234,834.04 | Pennsylvania |
| Rhode Island | 257.5 | 809,280.68 | 400,528.17 | 16.6 | | 16.6 | 81,305.62 | 40,652.81 | | 2.2 | 2.2 | 338,736.37 | Rhode Island |
| South Carolina | 2,008.6 | 2,477,211.20 | 1,054,161.02 | 56.9 | 37.3 | 94.2 | | | | | | 1,428,293.19 | South Carolina |
| South Dakota | 4,013.6 | 3,294,275.28 | 1,840,552.02 | 195.7 | 187.1 | 382.8 | 559,170.30 | 374,189.03 | 102.4 | | 102.4 | 1,099,884.78 | South Dakota |
| Tennessee | 1,675.0 | 495,757.91 | 245,741.70 | 16.4 | 4.4 | 20.8 | 936,864.17 | 452,877.48 | 35.8 | 6.3 | 42.1 | 3,629,666.12 | Tennessee |
| Texas | 7,577.1 | 15,000,607.30 | 6,795,296.07 | 770.5 | 180.3 | 950.8 | 2,257,585.26 | 1,015,744.04 | 148.6 | 49.9 | 198.5 | 5,848,160.10 | Texas |
| Utah | 1,218.5 | 690,137.33 | 482,342.89 | 61.0 | .4 | 61.4 | 576,880.17 | 426,866.26 | 37.1 | 25.9 | 63.0 | 1,142,460.84 | Utah |
| Vermont | 339.1 | 104,832.58 | 52,345.06 | 4.3 | | 4.3 | 239,646.33 | 112,035.00 | 7.5 | | 7.5 | 469,931.27 | Vermont |
| Virginia | 1,896.6 | 2,446,965.75 | 1,169,634.87 | 128.8 | 8.9 | 137.7 | 159,197.59 | 79,598.79 | 5.4 | | 5.4 | 2,040,053.01 | Virginia |
| Washington | 1,195.3 | 2,535,960.50 | 1,174,568.56 | 84.7 | | 84.7 | 705,650.41 | 337,300.00 | 16.9 | 4.5 | 21.4 | 1,446,042.23 | Washington |
| West Virginia | 882.9 | 1,825,407.92 | 806,803.60 | 44.7 | 10.5 | 55.2 | 97,329.39 | 40,854.05 | .6 | | .6 | 1,238,995.53 | West Virginia |
| Wisconsin | 2,672.7 | 3,441,720.15 | 1,367,098.99 | 131.1 | 7.8 | 138.9 | 364,236.86 | 126,900.00 | | 12.7 | 12.7 | 2,344,444.64 | Wisconsin |
| Wyoming | 2,022.3 | 2,616,975.90 | 1,563,970.41 | 194.0 | 84.1 | 278.1 | 560,645.85 | 362,514.57 | 17.5 | 65.0 | 82.5 | 595,980.54 | Wyoming |
| Hawaii | 65.2 | 897,832.22 | 411,665.59 | 27.9 | | 27.9 | 386,378.64 | 278,088.61 | 7.6 | | 7.6 | 1,762,851.99 | Hawaii |
| TOTALS | 100,697.5 | 198,941,063.74 | 93,018,412.23 | 6,716.0 | 1,724.0 | 8,440.0 | 55,562,478.22 | 25,234,648.16 | 2,200.2 | 984.9 | 3,185.1 | 94,453,478.07 | TOTALS |

[1] The term stage construction refers to additional work done on projects previously improved with Federal-aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.

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